



Pirelli Società per Azioni

Direzione Proprietà Industriale

July 1, 1999

0270/rm- 6322

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0049 89 2399 4465

Total pages transmitted: 58 (including this cover letter)

EUROPEAN PATENT OFFICE

Directorate 4.5.

Erhardstrasse 27

D-80298 Munchen

(Germany)

Applicant's ref. PC811

Re: Filing of a European Patent Application having for title:  
"AUTOPROTECTED OPTICAL COMMUNICATION RING NETWORK"  
in the name of PIRELLI CAVI E SISTEMI S.p.A.

Dear Sirs,

We are transmitting you the specification and the documents for filing the subject patent application, as indicated in the enclosed "Request for grant of a European Patent".

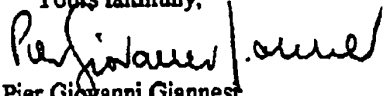
We are kindly requesting the Office to acknowledge safe receipt of this documentation by return fax - Telefax No. 0039 02 6442 3190.

The relative prescribed fees as well as the fee for the issue of receipt by fax, in the total amount of EUR 1252=- should be debited from "Deposit Account No. 28070089 in the name of Pirelli Cavi e Sistemi S.p.A., as per enclosed Debit Order.

Confirmation copy of the documents will be sent under separate cover.

With many thanks.

Yours faithfully,

  
Pier Giovanni Giannesi  
(G.A. 25553)

Viale Sarca, 222  
20126/Milano  
telefono 02.6442.1  
fax 02.6442.3190

Part.IVA 00886890151  
Registro Trib. Milano 197367  
CCIAA di Milano 576645

U.I.C. Iscrizione n.1745  
Capitale interamente versato  
L. 1.942.623.489.000



**Antrag auf Erteilung eines europäischen Patents / Request for grant of a European patent / Requête en délivrance d'un brevet européen**

Bestätigung einer bereits durch Telexkopie (Telex) eingereichten Anmeldung / Confirmation of an application already filed by facsimile / Confirmation d'une demande déjà déposée par télexcopie

Wenn ja, Datum der Übermittlung der Telexkopie und Name der Einreichungsbehörde / If yes, facsimile date and name of the authority with which the documents were filed / Si oui, date d'envoi de la télexcopie et nom de l'autorité de dépôt

☐ Ja / Yes / Oui

Datum / Data Berhanda / Authority / Auzon

Nur für amtlichen Gebrauch / For official use only / Cadre réservé à l'administration			
Anmeldenummer / Application No. / N° de la demande	MKEY	1	99112552.7
Tag des Eingangs (Regel 24(2)) / Date of receipt (Rule 24(2)) / Date de réception (règle 24(2))	DREC	2	01.07.99
Tag des Eingangs beim EPA (Regel 24(4)) / Date of receipt at EPO (Rule 24(4)) / Date de réception à l'OEB (règle 24(4))	RENA	3	
Anmelde tag / Date of filing / Date de dépôt		4	
<b>Tabulatoren-Positionen / Tabulation marks / Arrêt de tabulation</b> Es wird die Erteilung eines europäischen Patents beantragt / Grant of a European patent, and examination of the application under Article 94, are hereby requested / Il est demandé la délivrance d'un brevet européen et, conformément à l'article 94, l'examen de la demande <div style="text-align: center;">EXAM 4 <input type="checkbox"/></div>			
Zeichen des Anmelders oder Vertreters (max. 15 Positionen) / Applicant's or representative's reference (maximum 15 spaces) / Référence du demandeur ou du mandataire (max. 15 caractères ou espaces) <div style="text-align: center;">AREP</div>			
<b>ANWELDER / APPLICANT / DEMANDEUR</b> Name / Nom Anschrift / Address / Adresse <div style="text-align: center;">APPR 01 # 4161311816171</div> <div style="text-align: center;"># DEST #</div>			
Zustellanschrift / Address for correspondence / Adresse pour la correspondance <div style="text-align: center;">PADR</div>			
Staat des Wohnsitzes oder Sitzes / State of residence or of principal place of business / Etat du domicile ou du siège Staatsangehörigkeit / Nationality / Nationalité Telefon / Telephone / Téléphone Telex / Télec      Telefax / Fax / Télécab Weitere(n) Anmelder auf Zusatzblatt / Additional applicant(s) on additional sheet / Autre(s) demandeur(s) sur feuille additionnelle			
<b>VERTRETER / REPRESENTATIVE / MANDATAIRE:</b> Name / Nom (Nur einen Vertreter angeben, der in das europäische Patentregister eingetragen und an den zugestellt wird / Name only one representative, who is to be listed in the Register of European Patents and to whom notification is to be made / N'indiquer qu'un seul mandataire, qui sera inscrit au Registre européen des brevets et auquel notification sera faite) <div style="text-align: center;">FREP 01 1441016171 # # # # # # # # # #</div> Geschäftsanschrift / Address of place of business / Adresse professionnelle Telefon / Telephone / Téléphone Telex / Télec      Telefax / Fax / Télécab Weitere(n) Vertreter auf Zusatzblatt / Additional representative(s) on additional sheet / Autre(s) mandataire(s) sur feuille additionnelle			
Prüfungsantrag in einer zugelassenen Nichtmuttersprache (siehe Merkblatt II, 5): / Request for examination in an admissible non-EPO language (see Notes II, 5): / Requête en examen dans une langue non officielle autorisée (voir notice II, 5) Si richiede di esaminare la domanda ai sensi dell'Art. 94 EPC <div style="text-align: center;">PC 811</div>			
PIRELLI CAVI E SISTEMI S.p.A. Viale Sarca, 222 I-20126 MILAN, Italy			
ITALY ITALIAN			
Pier Giovanni GIANNESI PIRELLI S.p.A. Industrial Property Dept. Viale Sarca, 222 I-20126 MILAN, Italy 39 02 6442 3331 310135 PIREMI I - 39 02 6442 3190			
X			

PC811

Raum für Zeichen des Anmelders / Space for applicant's reference / Espace réservé à la référence du demandeur


Vollmacht / Authorization / Pouvoir: Ist beigelegt / Is enclosed / ci-joint	
Ist registriert unter Nummer / has been registered under No. / a été enregistré sous le n°	
GENA	
ERFINDER / INVENTOR / INVENTEUR:	
Anmelder ist (sind) alleinige(r) Erfinder / The applicant(s) is (are) the sole inventor(s) / Le(s) demandeur(s) est (sont) le (les) seul(s) inventeur(s)	
Erfindernennung auf gesondertem Schriftstück / Designation of inventor attached / Voir la désignation de l'inventeur ci-jointe	
BEZEICHNUNG DER ERFINDUNG / TITLE OF INVENTION / TITRE DE L'INVENTION:	
TIDE TIEN TIFR	
PRIORITÄTSEKLÄRUNG / DECLARATION OF PRIORITY / DECLARATION DE PRIORITE	
PRIO	
01 # . . . # . . . . .	
02 # . . . # . . . . .	
03 # . . . # . . . . .	
04 # . . . # . . . . .	
Weitere Prioritätserklärung(en) auf Zusatzblatt / Additional declaration(s) of priority on additional sheet / Autre(s) déclaration(s) de priorité sur feuille supplémentaire	
BIOLOGISCHES MATERIAL	
BIOLOGICAL MATERIAL	
Die Erfindung betrifft biologisches Material oder seine Verwendung, das nach Regel 28 hinterlegt worden ist	
The invention relates to and/or uses biological material deposited under Rule 28.	
BIOM 1 # . . . . . #	
Die Angaben nach Regel 28(1) c) sind in den technischen Anmeldeunterlagen enthalten auf / The particulars referred to in Rule 28(1) (c) are given in the technical documents in the application on / Les indications visées à la règle 28(1) c) figurent dans les pièces techniques de la demande à la / sur	
werden später mitgeteilt / will be submitted later / seront communiquées ultérieurement	
Die Empfangsbescheinigung(en) der Hinterlegungsstelle ist (sind) beigelegt / The receipt(s) of deposit issued by the depositary institution is (are) enclosed / Le(s) récépissé(s) de dépôt délivré(s) par l'autorité de dépôt est (sont) ci-joint(s)	
wird (werden) nachgereicht / will be filed later / sera (seront) produit(s) ultérieurement	
Verzicht auf die Verpflichtung des Antragstellers nach Regel 28(3) auf gesondertem Schriftstück / Waiver of the right to an undertaking from the requester pursuant to Rule 28(3) attached / Renonciation, sur document distinct, à l'engagement du requérant au titre de la règle 28(3)	

20	
21	25533 0.8 Nummer Number Numéro
22	
23	X
24	"AUTOPROTECTED OPTICAL COMMUNICATION RING NETWORK"
25	Staat / State / Etat Anmeldetag / Filing date / Date de dépôt Aktenzeichen / Application No. / N° de la demande
	2
	3
	4
26	NATIERE BIOLOGIQUE
	L'invention concerne et/ou utilise la matière biologique, déposée conformément à la règle 28.
27	Seite(n) / page(s) Zeile(n) / line(s) / ligne(s)
27a	
28	
28a	
29	

<p>Falls das biologische Material nicht vom Anmelder, sondern von einem Dritten hinterlegt wurde: / Where the biological material has been deposited by a person other than the applicant: / Lorsque la matière biologique a été déposée par une personne autre que le demandeur:</p> <p>Ermächtigung nach Regel 28(1)(d) / Authorisation under Rule 28(1)(d) / Autorisation en vertu de la règle 28(1)(d)</p> <p>Ist beigelegt / Is enclosed / est jointe</p> <p>Wird nachgereicht / Will be filed later / sera produit ultérieurement</p>	<p>30</p> <p>30 a</p> <p>30 b</p>	<p>Name und Anschrift des Hinterlegers / Name and address of depositor / Nom et adresse du déposant:</p>
<p>NUCLEOTID-UND AMINOSÄURESEQUENZEN / NUCLEOTIDE AND AMINO ACID SEQUENCES / SEQUENCES DE NUCLEOTIDES ET D'ACIDES AMINÉS</p> <p>Die Beschreibung enthält ein Sequenzprotokoll nach Regel 27a(1) / The description contains a sequence listing in accordance with Rule 27a(1) / La description contient une liste de séquences selon la règle 27bis(1)</p> <p>Der vorgeschriebene maschinenlesbare Datenträger ist beigelegt / The prescribed machine readable data carrier is enclosed / Le support de données prescrit déchiffirable par machine est annexé</p> <p>Es wird hiermit erklärt, daß die auf dem Datenträger gespeicherte Information mit dem schriftlichen Sequenzprotokoll übereinstimmt (Regel 27a(2)) / It is hereby stated that the information recorded on the data carrier is identical to the written sequence listing (Rule 27a(2)) / Il est déclaré par le présent que l'information figurant sur le support de données est identique à celle que contient la liste de séquences écrite (règle 27bis (2))</p>	<p>31</p>	<p>SEQL(1)</p>
<p>BEZEICHNUNG DER VERTRAGS-STAA TEN UND ERKLÄRUNGEN HIERZU</p> <p>DESIGNATION OF THE CONTRACTING STATES AND ASSOCIATED DECLARATIONS</p> <p>1. Hiermit werden sämtliche Vertragsstaaten des EPÜ benannt, die bei Einreichung dieser Anmeldung dem EPÜ angehören.</p> <p>1. All states which are Contracting States to the EPC at the filing of this application are hereby designated.</p> <p>2. Der Anmelder beabsichtigt derzeit, Benennungsgebühren für die nachfolgende angekreuzten Vertragsstaaten zu entrichten.</p> <p>2. The applicant currently intends to pay designation fees for the States marked below with a cross:</p> <p>DEST</p> <p><input type="checkbox"/> AT Österreich / Austria / Autriche</p> <p><input type="checkbox"/> BE Belgien / Belgium / Belgique</p> <p><input type="checkbox"/> CH/LI Schweiz und Liechtenstein / Switzerland and Liechtenstein / Suisse et Liechtenstein</p> <p><input type="checkbox"/> DE Deutschland / Germany / Allemagne</p> <p><input type="checkbox"/> DK Dänemark / Denmark / Danemark</p> <p><input type="checkbox"/> ES Spanien / Spain / Espagne</p> <p><input type="checkbox"/> FI Finnland / Finland / Finlande</p> <p><input type="checkbox"/> FR Frankreich / France / France</p> <p><input type="checkbox"/> CY Cypr</p> <p><input type="checkbox"/> _____</p> <p><input type="checkbox"/> _____</p> <p>(Place for designations, for the EPÜ nach Ausdeutung dieses Formblatts in Kraft tritt / Space for Contracting States for which the EPC enters into force after this form has been printed / Pour les Etats contractants à l'égard desquels la CBE entrera en vigueur après l'impression du présent formulaire)</p> <p>Es wird beantrag, für die unter Nr. 2 nicht angekreuzten Vertragsstaaten von der Zustellung von Mitteilungen nach Regel 65a (1) und Regel 69 (1) abzusehen.</p> <p>It is requested that no communications under Rule 65a (1) and Rule 69 (1) be notified concerning the Contracting States not marked with a cross under No.2.</p> <p>Ist ein automatischer Abbuchungsauftrag erteilt worden (Feld 43), so wird beantrag, bei Ablauf der Grundfrist nach Artikel 79 (2) EPÜ Benennungsgebühren nur für die unter Nr.2 angekreuzten Vertragsstaaten abzubuchen.</p> <p>If an automatic debit order has been given (section 43), it is requested that, when the basic period specified in Art. 79(2) expires, designation fees be debited only for the Contracting States marked with a cross under No.2.</p>	<p>32</p>	<p>DÉSIGNATION D'ETATS CONTRACTANTS ET DÉCLARATIONS A CE PROPOS</p> <p><input checked="" type="checkbox"/> 1. Sont désignées tous les Etats qui sont des Etats contractants de la CBE à la date du dépôt de la présente demande.</p> <p>2. Le demandeur se propose actuellement de payer des taxes de désignation pour les Etats cochés ci-dessous:</p> <p><input type="checkbox"/> GB Vereinigtes Königreich / United Kingdom / Royaume-Uni</p> <p><input type="checkbox"/> GR Griechenland / Greece / Grèce</p> <p><input type="checkbox"/> IE Irland / Ireland / Irlande</p> <p><input type="checkbox"/> IT Italien / Italy / Italia</p> <p><input type="checkbox"/> LU Luxemburg / Luxembourg / Luxembourg</p> <p><input type="checkbox"/> MC Monaco / Monaco / Monaco</p> <p><input type="checkbox"/> NL Niederlande / Netherlands / Pays-Bas</p> <p><input type="checkbox"/> PT Portugal / Portugal / Portugal</p> <p><input type="checkbox"/> SE Schweden / Sweden / Suède</p> <p><input type="checkbox"/> _____</p> <p><input type="checkbox"/> _____</p> <p><input checked="" type="checkbox"/> Prière de ne pas procéder à la signification des notifications prévues par les règles 65bis (1) et 69 (1) pour les Etats contractants n'ayant pas été cochés au no 2.</p> <p>Si un ordre de prélèvement automatique a été donné (rubrique 43), prière de ne prélever à l'expiration des délais de base tels que définis à l'article 79(2) que les taxes de désignation pour les Etats contractants cochés au no 2.</p>

<p>Verschiedene Anmelder für verschiedene Vertragsstaaten / Different applicants for different Contracting States / Différents demandeurs pour différents Etats contractants</p> <p>APPR 02 # <input type="text"/> # <input type="text"/></p>	<p>33 Name(n) des (der) Anmelder(s) und benannte Vertragsstaaten / Name(s) of applicant(s) and designated Contracting States / Nom(s) du (des) demandeur(s) et des Etats contractants désignés</p>																								
<p><b>ERSTRECKUNG DES EUROPÄISCHEN PATENTS</b></p> <p>Diese Anmeldung gilt als Antrag, die europäische Patentanmeldung und das darauf erhaltene europäische Patent auf alle Nicht-Vertragsstaaten des EPÜ zu erstrecken, mit denen am Tag ihrer Einreichung „Erstreckungsabkommen“ bestehen (Derzeit: Albanien, Litauen, Lettland, Rumänien, Slowenien). Die Erstreckung wird jedoch nur wirksam, wenn die vorgeschriebene Erstreckungsgebühr entrichtet wird.</p> <p><b>EXTENSION OF THE EUROPEAN PATENT</b></p> <p>This application is deemed to be a request to extend the European patent application and the European patent granted in respect of it to all non-Contracting States to the EPC with which "extension agreements" exist on the date on which the application is filed (Present situation: Albania, Lithuania, Latvia, Romania, Slovenia). However, the extension only takes effect if the prescribed extension fee is paid.</p> <p><b>EXPT</b></p> <p>Der Anmelder beabsichtigt derzeit, die Erstreckungsgebühr für die nachfolgend angekreuzten Staaten zu entrichten: / The applicant currently intends to pay the extension fee for the States marked below with a cross: / Le demandeur se propose actuellement d'acquiescer la taxe d'extension pour les Etats dont le nom est coché ci-après:</p> <table border="0"> <tr> <td>Albanien / Albania / Albanie</td> <td>AL</td> <td><input type="checkbox"/></td> </tr> <tr> <td>Litauen / Lithuania / Lituanie</td> <td>LT</td> <td><input type="checkbox"/></td> </tr> <tr> <td>Lettland / Latvia / Lettonie</td> <td>LV</td> <td><input type="checkbox"/></td> </tr> <tr> <td>Rumänien / Romania / Roumanie</td> <td>RO</td> <td><input type="checkbox"/></td> </tr> <tr> <td>Slowenien / Slovenia / Slovénie</td> <td>SI</td> <td><input type="checkbox"/></td> </tr> <tr> <td>_____</td> <td>_____</td> <td><input type="checkbox"/></td> </tr> <tr> <td>_____</td> <td>_____</td> <td><input type="checkbox"/></td> </tr> <tr> <td>_____</td> <td>_____</td> <td><input type="checkbox"/></td> </tr> </table> <p><small>(Platz für Staaten, mit denen nach Drucklegung dieses Formblatts „Erstreckungsabkommen“ in Kraft treten) / space for States with which "extension agreements" enter into force after this form has been printed) / (Place pour des Etats à l'égard desquels des accords d'extension entreraient en vigueur après l'impression du présent formulaire)</small></p>	Albanien / Albania / Albanie	AL	<input type="checkbox"/>	Litauen / Lithuania / Lituanie	LT	<input type="checkbox"/>	Lettland / Latvia / Lettonie	LV	<input type="checkbox"/>	Rumänien / Romania / Roumanie	RO	<input type="checkbox"/>	Slowenien / Slovenia / Slovénie	SI	<input type="checkbox"/>	_____	_____	<input type="checkbox"/>	_____	_____	<input type="checkbox"/>	_____	_____	<input type="checkbox"/>	<p>34 <b>EXTENSION DES EFFETS DU BREVET EUROPEEN</b></p> <p>La présente demande est réputée constituer une requête en extension des effets de la demande de brevet européen et du brevet européen délivré sur la base de cette demande à tous les Etats non parties à la CBE avec lesquels il existe un "accord d'extension" à la date du dépôt de la demande (Situation actuelle: Albanie, Lituanie, Lettonie, Roumanie, Slovénie). Toutefois l'extension ne produit ses effets que s'il est acquitté la taxe d'extension prescrite.</p>
Albanien / Albania / Albanie	AL	<input type="checkbox"/>																							
Litauen / Lithuania / Lituanie	LT	<input type="checkbox"/>																							
Lettland / Latvia / Lettonie	LV	<input type="checkbox"/>																							
Rumänien / Romania / Roumanie	RO	<input type="checkbox"/>																							
Slowenien / Slovenia / Slovénie	SI	<input type="checkbox"/>																							
_____	_____	<input type="checkbox"/>																							
_____	_____	<input type="checkbox"/>																							
_____	_____	<input type="checkbox"/>																							
<p>Die Anmeldung ist eine Teilanmeldung / The application is a divisional application / La présente demande constitue une demande divisionnaire</p> <p>DFIL 9 <input type="text"/> # <input type="text"/></p> <p>PANR <input type="text"/> # <input type="text"/></p>	<p>35 <input type="text"/> Nummer der früheren Anmeldung No. of earlier application Numéro de la demande initiale</p>																								
<p>Es handelt sich um eine Anmeldung nach Art. 61(1)(b) / The application is an Art. 61(1)(b) application / La présente demande constitue une demande selon l'article 61(1)(b)</p> <p>DFIL 9 <input type="text"/> # <input type="text"/></p> <p>EANR <input type="text"/> # <input type="text"/></p>	<p>36 <input type="text"/> Nummer der früheren Anmeldung No. of earlier application Numéro de la demande initiale</p>																								
<p>Patentansprüche / Claims / Revendications</p> <p>CLMS <input type="text"/></p>	<p>37 <input type="text"/> 20 Zahl der Patentansprüche Number of claims Nombre de revendications</p>																								
<p>Zur Veröffentlichung mit der Zusammenfassung wird vorgeschlagen Abbildung Nr. / With the abstract it is proposed to publish figure No. / Il est proposé de publier avec l'abrégé la figure n°</p> <p>DRAW (2) <input type="text"/></p>	<p>38 <input type="text"/> Fig 2 Nummer / Number / Numéro</p>																								

5

Zusätzliche Abschrift(en) der im europäischen Recherchenbericht angeführten Schriftstücke wird (werden) beantragt / Additional copy(ies) of the documents cited in the European search report is (are) requested / Prière de fournir une (des) copie(s) supplémentaire(s) des documents cités dans le rapport de recherche européenne <b>ASOC</b>	40 <input type="text"/> Anzahl der zusätzlichen Sätze von Abschriften Number of additional sets of copies Nombre de jeux supplémentaires de copies
Es wird die Rückerstattung der Recherchengebühr gemäß Art. 10 GebO beantragt / Refund of the search fee is requested pursuant to Article 10 of the Rules relating to Fees / Le remboursement de la taxe de recherche est demandé en vertu de l'article 10 du règlement relatif aux taxes Eine Kopie des Recherchenberichts ist beigelegt / A copy of the search report is attached / Une copie du rapport de recherche est jointe	41 <input type="text"/> 42 <input type="text"/>
<b>AUTOMATISCHER ABBUCHUNGSauftrag</b> (nur möglich für Inhaber von beim EPA geführten laufenden Konten) <b>AUTOMATIC DEBIT ORDER</b> (for EPO deposit account holders only) <b>ORDRE DE PRELEVEMENT AUTOMATIQUE</b> (uniquement possible pour les titulaires de comptes courants ouverts auprès de l'OEB) Das Europäische Patentamt wird hiermit beauftrag, fällig werdende Gebühren und Auslagen nach Maßgabe der Vorschriften über das automatische Abbuchungsverfahren vom nebenstehenden laufenden Konto abzubuchen / The European Patent Office is hereby authorised, under the Arrangements for the automatic debiting procedure, to debit from the deposit account opposite any fees and costs falling due / Par la présente, il est demandé à l'Office européen des brevets de prélever du compte courant ci-contre les taxes et frais venant à échéance, conformément à la réglementation relative au prélèvement automatique <b>DECA</b>	<b>FÜR AUTOMATISCHEN ABBUCHUNGSauftrag:</b> <b>FOR AUTOMATIC DEBIT ORDER:</b> <b>POUR L'ORDRE DE PRELEVEMENT AUTOMATIQUE</b> Nummer des laufenden Kontos / Name des Kontoinhabers / Deposit account number / Account holder's name / Numéro du compte courant Nom du titulaire du compte 43 <input type="text"/>
Eventuelle RÜCKZAHLUNGEN auf das nebenstehende beim EPA geführte laufende Konto / REMBURSEMENTS éventuels à effectuer sur le compte courant ci-contre ouvert auprès de l'OEB <b>DEPA</b>	Nummer des laufenden Kontos / Name des Kontoinhabers / Deposit account number / Account holder's name / Numéro du compte courant Nom du titulaire du compte 44 <b>28070089</b>
Die vorgeschriebene Liste über die diesem Antrag beigelegten Unterlagen ergibt sich aus der vorbereiteten Empfangsbescheinigung (Seite 6 dieses Antrages) The prescribed list of documents enclosed with this request is shown on the prepared receipt (page 6 of this request)	45 <input type="text"/> La liste prescrite des documents joints à cette requête figure sur le récépissé préalable (page 6 de la présente requête)
Unterschriften des (der) Anmelders(s) oder Vertreters(s) / Signature(s) of applicant(s) or representative(s) / Signature(s) du (des) demandeur(s) ou du (des) mandataire(s) Ort / Place / Lieu <b>Milan, Italy</b>	46 <input type="text"/> Für Angestellte nach Artikel 133(3) Satz 1 mit allgemeiner Vollmacht / For employees under Article 133(3), 1st sentence, having a general authorisation / Pour les employés mentionnés à l'article 133(3), 1 <sup>ère</sup> phrase, munis d'un pouvoir général Nr. No. / n°:
Datum / Date <b>July 1, 1999</b>  <b>Pier Giovanni GIANNESE</b> (G.A. 25553) Name des (der) Unterschrifters bitte mit Schreibmaschine wiederholen. Bei juristischen Personen bitte die Stellung des (der) Unterschrifters innerhalb der Gesellschaft mit Schreibmaschine angeben. / Please type name under signature. In case of legal persons, the position of the signatory within the company should also be typed. / Le ou les noms des signataires doivent être également dactylographiés et être d'une personne morale, la position occupée au sein de celle-ci par le ou les signataires sera indiquée à la machine à écrire.	

**Empfangsbescheinigung / Receipt for documents / Récépissé de documents 6**

(Liste der diesem Antrag beigelegten Unterlagen)

(Checklist of enclosed documents)

(Liste des documents annexés à la présente requête)

Es wird hiermit der Empfang der unten bezeichneten Dokumente bescheinigt / Receipt of the documents indicated below is hereby acknowledged / Nous attestons le dépôt des documents désignés ci-dessous

Wird im Falle der Einreichung der europäischen Patentanmeldung bei einer nationalen Behörde diese Empfangsbescheinigung vom Europäischen Patentamt übersandt, so ist sie als Mitteilung gemäß Regel 24(4) anzusehen (siehe Feld RENA). Nach Erhalt der Mitteilung nach Regel 24(4) sind alle weiteren Unterlagen, die die Anmeldung betreffen, nur noch unmittelbar beim EPA einzureichen. / If this receipt is issued by the European Patent Office and the European patent application was filed with a national authority it serves as a communication under Rule 24(4) (see Section RENA). Once the communication under Rule 24(4) has been received, all further documents relating to the application must be sent directly to the European Patent Office. / Si, en cas de dépôt de la demande de brevet européen auprès d'un



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Pier Giovanni GIANNESI  
PIRELLI S.p.A.  
Industrial Property Dept.  
Viale Sarca, 222  
I-20126 MILANO (IT)

☐ Applicant: PIRELLI CAVI E SISTEMI S.p.A.

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Anmeldenummer / Application No. / N° de demande		99112552.7	
Tag des Eingangs (Regel 24(2)) / Date of receipt (Rule 24(2)) / Date de réception (règle 24(2))	DREC	01.07.99	
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Tag des Eingangs beim EPA (Regel 24(4)) / Date of receipt at EPO (Rule 24(4)) / Date de réception à l'OEB (règle 24(4))	RENA		
A. Anmeldungsurkunden und Prioritätsbelege / Application documents and priority document(s) / Pièces de la demande et document(s) de priorité	47	Stückzahl / Number of copies / Nombre d'exemplaire	Blaßzahl eines Blatts / Number of sheets in each copy / Nombre de feuilles par exemplaire
1. Beschreibung / Description		1	30
2. Patentansprüche / Claim(s) / Revendication(s)		1	6
3. Zeichnung(en) / Drawing(s) / Dessin(s)		1	11
4. Zusammenfassung / Abstract / Abrégé		1	1
5. Übersetzung der Anmeldungsurkunden / Translation of the application documents / Traduction des pièces de la demande			
6. Prioritätsbeleg(e) / Priority document(s) / Document(s) de priorité			
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**\*AUTOPROTECTED OPTICAL COMMUNICATION RING  
NETWORK\***

In Sachen der obenbezeichneten europäischen Patentanmeldung nennt (nennen) der (die) Unterzeichnete(n)<sup>1</sup>  
In respect of the above European Patent Application I (we), the undersigned<sup>1</sup>  
En ce qui concerne la demande de brevet européen susmentionnée le(s) soussigné(s)<sup>1</sup>

**PIRELLI CAVI E SISTEMI S.p.A.**  
**Viale Sarca, 222**  
**I-20126 MILAN**  
**Italy**

als Erfinder<sup>2</sup>:  
do hereby designate as inventor(s)<sup>2</sup>:  
désigne(m) en tant qu'inventeur(s)<sup>2</sup>:

1) **Fulvio ARECCO**  
**Via Mercadante, 29/A**  
**20052 MONZA (MI)**  
**Italy**

2) **Valerio VISCARDI**  
**Via Monte Santo, 28**  
**20037 PADERNO DUGNANO (MI)**  
**Italy**

☐ (Weitere Erfinder sind auf einem gesonderten Blatt angegeben)/(Additional inventors indicated on supplementary sheet)/  
(les autres inventeurs sont mentionnés sur une feuille supplémentaire).

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Ort/place/tieu Milan, Italy

Datum/date July 1, 1999

Unterschrift(en) des (der) Anmelder(s) oder Vertreter(s)/  
Signature(s) of applicant(s) or representative(s)/  
Signature(s) du (des) demandeur(s) ou du (des) mandataire(s)

*Pier Giovanni Giannesi*  
**Pier Giovanni GIANNESI**  
**GA 25553**

Name des (der) Unterzeichneten bitte mit Schreibmaschine wiederholen. Bei juristischen Personen bitte die Stellung des (der) Unterzeichneten innerhalb der Gesellschaft mit Schreibmaschine angeben/Please type name under signature in case of legal persons, the position of the signer within the company should also be typed/Le ou les noms des signataires doivent être également dactylographiés. S'il s'agit d'une personne morale, la position occupée au sein de celle-ci par le ou les signataires sera indiquée à la machine à écrire

**Applicant's reference: PC811**

As additional Representative is appointed:

Paolo GUELLA

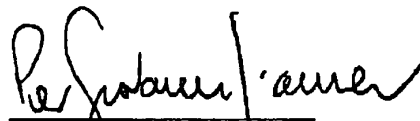
PIRELLI S.p.A.  
Industrial Property Dept.  
Viale Sarca, 222  
I-20126 MILANO (Italy)  
Telephone: + 39 02 6442 - 2545

Carlo BOTTERO

PIRELLI S.p.A.  
Industrial Property Dept.  
Viale Sarca, 222  
I-20126 MILANO (Italy)  
Telephone: + 39 02 6442 - 2064

Milano, Italy

July 1, 1999

  
Pier Giovanni GIANNESI  
(G.A. 25553)

\* \* \* SENDEBERICHT ( 2. JUL. 1999 9:13 ) \* \* \*

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# : SAMMELOBERTRAGUNG  
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S : STANDARD-AUFLÖSUNG  
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E : ECM-FEHLERKORREKTUR  
) : VERKLEINERUNG

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**AUTOPROTECTED OPTICAL COMMUNICATION RING NETWORK**

The present invention relates to an autoprotected optical communication ring network, in particular a WDM (Wavelength Division Multiplexing) autoprotected optical communication ring network of the type including a plurality of nodes connected to each other in pairs by means of respective optical connections susceptible to failure, each connection comprising at least a first and a second optical carrier having opposite transmission directions.

"Optical communication ring network" here means not only a communication network configured as a whole as a ring but, in general, any section of a network comprising a plurality of nodes and branches and arranged, at least temporarily, in a ring configuration.

Specifically, the present invention tackles the problem of making a ring network with self-healing capabilities, i.e. capabilities of managing failures which may arise in the connections between the network nodes.

"Failure" here means any event which may affect the physical optical carriers (e.g. breakage or interruption of an optical fiber) and/or the devices of the network operating on the transmitted signals (e.g. receivers, demultiplexers, amplifiers, etc.), in such a way as to bring about a situation of degradation of the transmission which is deemed not tolerable; the term "failure" thus should in no way be interpreted as being limited only to events causing the complete interruption of the connection.

The state of the art includes many methods to optically protect a set of wavelength multiplexed optical channels carried by a two-fiber optical ring network.

European Patent Application No. 769859 in the name of the Applicant relates to a transparent optical self-healing-ring communication network in which at least two nodes are optically connected along a first and a second closed optical path having opposite transmission directions. Each node simultaneously feeds its transmitted signals to the first and the second closed optical path, so that the signals travel along complementary arcs of the ring. The receiving node selectively receives the signals from one of the two closed paths and, in case of failure on this closed path, switches reception on the other closed path. The Applicant observes that this Optical Channel Protection method, identifiable as a "Optical Channel 1+1 Dedicated Ring Protection" method, requires that, for each wavelength used on one closed path, the same wavelength cannot be used on the other closed path other than for protection. Thus, with N wavelengths, only N protected channels can be used in the network.

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- European Patent Application No. 97123013.1-2209 filed on 31/12/97 in the name of the Applicant relates to a method and an apparatus for transparent optical communication with two-fiber bidirectional ring with autoprotection and management of low priority traffic. The communication network comprises two optical fibers (an external one and an internal one) that interconnect the nodes. According to the proposed technique, if a first and a second node of the network are considered for mutual signal transmission, a high-priority traffic can be set up on a first bidirectional communication path defined between the two nodes on the external and internal fibers, using only an arc of the communication ring defined between the two nodes.
- 10 The arc complementary to that just described can be used as a second bidirectional communication path between the two nodes for low-priority traffic, using the same wavelength as the preceding channel. The protection mechanism consists of redirecting the high-priority traffic onto the second path in the case of a breakdown in, or degradation of, communication on the first path, thus losing the low-priority traffic on the second path. This protection method is identifiable as a "Optical Channel 1:1 Dedicated Ring Protection" method with management of Low-Priority traffic. The Applicant observes that, although this method provides a double capacity with respect to the previous technique, with N wavelengths it is still not possible to protect more than N channels.
- 20 The article "A Transparent, All-Optical, Metropolitan Network Experiment in a Field Environment: The "PROMETEO" Self-Healing Ring", F. Arecco et al., IEEE Journal of Lightwave Technology, Vol.5, Dec 1997, describes a method to provide protection against failures in a metropolitan ring network. According to this method, a working fiber ring is used to carry all the optical channels between nodes, while a protection fiber ring is empty under normal operating conditions. In case of failure, a protection switching takes place at the nodes adjacent to the failure, which reconfigure in such a way to route all the optical channels (i.e. all the wavelengths of the multiplex section) through the protection fiber ring so as to bypass the failure. This protection method is known as "Optical Multiplex Section Protection" method.
- 30 The Applicant observes that, once more, with N wavelengths it is possible to carry only N protected channels. Moreover, the Applicant further observes that, in this case, it is not possible to have different protection mechanisms (i.e. protection at different layers) for different channels, and that the optical path after a protection reconfiguration can be longer than the ring circumference.
- 35 U.S. Patent No. 5,647,035 in the name of CSELT - Centro Studi e Laboratori Telecomunicazioni S.p.A. - provides a ring network communication structure on an

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optical carrier and a reconfigurable node for said structure. In said structure, a plurality of nodes are interconnected by means of connections comprising at least a first and a second optical carrier, such as an optical fiber. Transmission between two nodes occurs on the ring according to a WDM scheme, by utilizing a first wavelength for communication in one direction on the first carrier and a second wavelength for communication in the opposite direction on the second carrier. The second wavelength on the first carrier and the first wavelength on the second carrier are reserved for protection (protection channels) and are "shared" among all the nodes. Under regular operation conditions of the network, in each node the signals conveyed by the two fibers are detected, processed as required in units of a higher hierarchical level, converted again in optical signals and re-transmitted towards the following node. In the presence of a failure on one of the connections, the nodes adjacent to the failed connection reconfigure themselves to ensure the continuation of communication on the alternative path provided by the ring, by utilizing the first wavelength on the second carrier and the second wavelength on the first carrier. The exemplary embodiment described referring to just two wavelengths  $\lambda_1$ ,  $\lambda_2$ , can be generalized to any number of wavelengths with a corresponding expansion of the described connection; switching matrices of the nxn type may be used.

The Applicant noticed that, in the ring network proposed in US 5,647,035, if multi-wavelength signals have to be managed, since signal re-routing is localized at the nodes adjacent to the failure, the protection operations have to be performed on the entire set of wavelengths of the multiplex section (as described for SDH in ITU-T Recommendation G-803 and G-841) and the reconfigured nodes must re-route all the working channels previously sent on the damaged ring segment to their respective protection channels running onto the complementary ring arc. This technique is then identifiable as an "Optical Multiplex Section Shared Protection" technique. Thence, each node in the network must be equipped with the optical switching tools for the complete set of wavelengths in the ring, and a switch matrix is then needed with a complexity which increases considerably with increasing the number of channels (e.g. if each channel carries 2.5 Gb/s and the system is adapted to transmit 16 channels, each matrix must be able to switch 16 x 2.5 Gb/s). It can be demonstrated that, in this case, the required optical switching blocks to protect a number of links between N and MN/2 (where N is the number of wavelengths and M the number of nodes) is always MN.

Furthermore, the Applicant observes that, in the Optical Multiplex Section Shared Protection, since the failure control is performed at the multiplex section

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level, a failure on a single optical channel (e.g. when a node transmitter is damaged) can be either ignored or it can cause the reconfiguration of all the traffic thus causing a temporary failure on all the other working channels.

The Applicant further observes that, in case such a network is reconfigured as a consequence of a failure, the protection path of a generic optical channel may be longer than the maximum ring circumference. This can occur when a generic bidirectional link is set up between two non-adjacent nodes in the network, as illustrated in Figure 1a (where nodes A and D are involved). In case of failure the switching action is performed by the two nodes adjacent to the failure (i.e. nodes B and C), as shown in Figure 1b. Briefly, each channel of the bidirectional link travels along the working path from the source node to one of the reconfigured nodes where it is routed into the protection path. Then it travels in opposite direction along all the ring network to the other reconfigured node where it is routed again on the working path and, finally, it reaches the destination node. This alternative optical channel path may have a length exceeding the ring circumference, reaching values of several hundred kilometers and then introducing low levels of S/N ratio and high levels of attenuation. In case of a transoceanic application, this protection solution may lead, due to loopbacks, to restoration transmission paths that would cross the ocean three times.

To overcome this last problem, a different protection solution has been proposed, which is referred to as a "MS shared protection ring - transoceanic application" in the Annex A of the Telecommunication standard ITU-T Recommendation G.841. In brief, a failure is detected at the two nodes adjacent to the failure at the SDH multiplex section layer and, subsequently, the nodes terminating failed links are informed of the failure situation and re-route the corresponding links on the complementary ring arc path, as illustrated in Figure 1c. In other words, in case of failure, all the transmission links affected by the failure are bridged at their source nodes onto the protection channels that travels away from the failure. When the affected links reach their final destination nodes, they are switched to their original drop point. Therefore, no loopbacks are established and there is no risk of having, in case of failure, restoration transmission paths crossing more times the ocean.

The Applicant observed that, in this case, as in the protection solution of U.S. Patent No. 5,647,035, the failure control is over the entire optical multiplex section and, therefore, a failure on a single optical channel may be either ignored or it can

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cause the reconfiguration of all the traffic thus causing a temporary failure on all the other working channels.

The Applicant further observes that a protection at the SDH layer requires a relatively complex electronic layout and can operate only at a predetermined bit rate.

- 5       The Applicant proposes, with the present invention, an improved type of shared protection technique, in which re-routing operations are performed only at the nodes which terminate affected links and only on the failed channels, thus avoiding the drawbacks related to re-routing operations on the multiplex section, and by using an optical reconfigurable connection mechanism which allows the omission of a SDH  
10 layer protection mechanism. Moreover, the failure control is performed at the channel level instead of at the multiplex section level, thus avoiding the above mentioned drawbacks.

- 15       In the proposed network, the nodes communicate in pairs defining bidirectional links, and, under normal conditions, are optically configured so as to exchange signals on a respective working arc path at a respective first wavelength on a first carrier of the network and at a respective second wavelength on a second carrier of the network; in the complementary arc, the same wavelengths may be used in the same manner to define other links, while the first wavelength on the second carrier and the second wavelength on the first carrier are reserved for protection and are  
20 used in case of failure affecting one of said links. Each node of the proposed network is provided with a pair of OADM (Optical Add/Drop Multiplexers) for extracting from, and inserting in, the optical multiplex section, only the channels which the node is adapted to operate on. All the remaining channels are passed-through. Each node is further provided with a receiving/transmitting module for each pair of wavelengths  
25 defining a transmission link, said module optically connecting, in a selective way, the OADMs to optical transmitters and receivers operating at said wavelengths. Each receiving/transmitting module performs failure control and re-routing operations on the two corresponding wavelengths. Consequently, in case of failure, if one of the links managed by this node is failed, the corresponding receiving/transmitting  
30 module, after detecting the failure by checking the channels status, is reconfigured in order to optically re-route the transmission on the complementary portion of the ring. The same operation is performed by the node at the other end of the failed link. Therefore, only the nodes managing affected links are optically reconfigured and only the failed channels (instead of the global multiplex section) are re-routed.

- 35       The protection technique of the invention provides the following advantages:  
- By operating protection at the channel level, it is possible to provide optical

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protection to a selected subset of optical channels and leave to other layers (e.g. SDH) or to other optical protection mechanisms the protection of the remaining channels.

5 - Using an optical re-routing technique, it is possible to omit the SDH protection layer, thus simplifying the node structure and allowing a direct connection to the ring network for clients using different protocols (possibly unprotected) like ATM, IP, etc. The proposed protection technique is therefore compatible with every client electronic transmission protocol.

10 - The receiving/transmitting module in the protection scheme of the invention includes an optical switching unit which, differently from SDH switching layouts, can operate at different bit rates (for example 155 Mbit/s, 622 Mbit/s, 2,5 Gbit/s, 10 Gbit/s)

15 - The protection technique of the invention allows a client to client protection, since a failure is detectable even if it affects a single channel, while generally the prior art techniques allow only global failure detection on the multiplexed flux (by using threshold photodiodes).

20 - The number of switching blocks is always two times the number of protected channels (i.e. between  $2N$  and  $MN$ , where  $N$  is the number of wavelengths and  $M$  the number of nodes) thus giving an advantage, with mixed traffic patterns, over the Optical Multiplex Section Shared Protection schema proposed in US 5,647,035. For example, with a typical 8 nodes, 32 wavelengths optical ring network ( $M=8$ ,  $N=32$ ), the required number of switching blocks for said Optical Multiplex Section Shared Protection schema is always 256, while by using the Optical Channel Shared Protection schema of the invention the required number of switching blocks varies  
25 between 64 (in case of "hub traffic", i.e. one node communicating with all the other nodes) and 256 (in case of "uniform traffic", i.e. one node communicating only with its two adjacent nodes).

30 - Since the reconfiguration takes place at the channel level instead of at the multiplex section level as in US 5,647,035, it is no more needed to provide each node with a switching equipment to perform protection on all the network channels (In particular it is then not necessary to use complex switch matrix as in the Optical Multiplex Section Shared Protection schema).

35 - Differently from the Optical Multiplex Section Shared Protection scheme proposed in US 5,647,035, the complexity of the node switching structure depends only on the number of links managed by the nodes and does not depend on the number of wavelengths in the network.

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- Differently from the Optical Multiplex Section Shared Protection scheme proposed in US 5,647,035, switching operations are performed externally to the network, and then no transitories are present. In particular, switching of the single channel is performed, as described below, between the receiving and the transmitting transponders and, therefore, the multiplexed optical flux conditions at the input of the node amplifier are substantially unchanged and then sudden power variations inside the network are avoided.

According to a first aspect, the present invention relates to an autoprotected optical communication ring network, including a first and a second optical carrier having opposite transmission directions and a plurality of optically reconfigurable nodes optically connected along the first and the second optical carrier and adapted to communicate in pairs by means of respective links susceptible of failure, the ring network having a normal operative condition in which the nodes of each pair are optically configured so as to exchange optical signals on a respective working arc path at a respective first wavelength on the first carrier and at a respective second wavelength different from said first wavelength on the second carrier, said respective working path having a complementary arc path defining a respective protection arc path in which the first wavelength on the first carrier and the second wavelength on the second carrier can be used for further links and the first wavelength on the second carrier and the second wavelength on the first carrier are reserved for protection, characterized in that the ring network has a failure operative condition in which the nodes terminating a failed link are optically reconfigured so as to exchange optical signals on the respective protection arc path at the respective second wavelength on the first carrier and at the respective first wavelength on the second carrier.

Preferably, each of said plurality of reconfigurable nodes is adapted to manage a predetermined subset of wavelengths within a set of transmission wavelengths and includes a first and a second optical add/drop multiplexer serially connected to said first and, respectively, second carrier to feed/extract said subset of wavelengths to/from said first and, respectively, second carrier, and to pass-through the remaining wavelengths of the set of transmission wavelengths.

Each of said plurality of reconfigurable nodes preferably includes at least an optical transmitter, at least an optical receiver and a reconfigurable optical switch unit selectively coupling said optical transmitter and said receiver to said first and second carriers.

Each of said plurality of reconfigurable nodes may include information

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insertion devices selectively optically connectable to said at least an optical transmitter and adapted to insert signalling information into the optical signals and information extraction devices selectively optically connectable to said at least an optical receiver and adapted to extract signalling information from the optical signals.

- 5        Said information insertion devices and said information extraction devices may include optical transponders optically coupling said optical switch unit to said first and second carrier and adapted to change the signals wavelengths.

According to a second aspect, the present invention relates to a method to autoprotect an optical ring network, said ring network including a first and a second  
10    optical carrier having opposite transmission directions and a plurality of nodes optically connected along the first and the second optical carrier and adapted to communicate in pairs in order to define bidirectional links, each pair including a first and a second link termination node adapted to mutually communicate at respective first and second wavelengths, the method including:

- 15    - exchanging signals between the first and the second link termination node of each pair on a respective working arc path of said ring network by using the respective first wavelength on the first carrier and the respective second wavelength on the second carrier; said respective working path having a complementary arc path defining a respective protection arc path in which the  
20    first wavelength on the first carrier and the second wavelength on the second carrier can be used for further links and the first wavelength on the second carrier and the second wavelength on the first carrier are reserved for protection;
- checking if a failure is present in the ring network producing at least a failed link; and
- 25    - optically reconfiguring, in the presence of a failure, the link terminating nodes of said at least a failed link so that they exchange signals on the respective protection arc path by using the respective first wavelength on the second carrier and the respective first wavelength on the second carrier.

Preferably, each node of said plurality of nodes is adapted to manage a  
30    predetermined subset of wavelengths within a set of transmission wavelengths carried by the first and the second carrier, said step of exchanging including optically separating, at each node of said plurality of nodes, each wavelength of the respective subset of wavelengths from the set of transmission wavelengths.

The step of checking may include verifying, in each node of said plurality of  
35    nodes and for each wavelength of the respective set of wavelengths, if signals are received.

The step of checking may include verifying, in each node of said plurality of nodes and for each wavelength of the respective set of wavelengths, if signals are received degraded.

5 The step of checking may include verifying, in each node of said plurality of nodes and for each wavelength of the respective set of wavelengths, if signals include a failure message.

The method may further include transmitting a failure message from a first link termination node of a pair to a second link termination node of the same pair if a signal transmitted from the second link termination node to the first link termination  
10 node is not received, or is received degraded, by the first link termination node.

Advantageously, the step of reconfiguring includes switching optical connections which selectively couple at least an optical transmitter and an optical receiver to said first and second carrier.

15 Preferably, the step of exchanging includes feeding at each of said plurality of nodes the corresponding subset of wavelengths to said first and, respectively, second carrier.

The step of exchanging signals may include the following steps executed in the first link termination node of a pair:

- generating an optical signal carrying an information;
- 20 - converting the optical signal in a electrical signal;
- adding to the electrical signal further information;
- reconverting the electrical signal in an optical signal provided with a predetermined wavelength adapted for transmission; and
- feeding the optical signal at the predetermined wavelength to either the first or  
25 the second carrier;

and the following steps executed in the second link termination node of the same pair:

- receiving the optical signal at the predetermined wavelength from either the first or the second carrier;
- 30 - converting the optical signal at the predetermined wavelength in an electrical signal;
- extracting from the electrical signal the further information;
- reconverting the electrical signal in an optical signal with a wavelength adapted for reception; and
- 35 - receiving the optical signal with the wavelength adapted for reception.

According to a further aspect, the present invention relates to a

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reconfigurable node for an autoprotected optical communication ring network, comprising a receiving/transmitting module including:

- an optical transmitter to generate a signal including information to be transmitted in the network;
- 5 - an optical receiver to receive a signal including information transmitted in the network;
- a first transmitting transponder for optically coupling to a first carrier of the network and adapted to modulate a signal at a first wavelength;
- a second transmitting transponder for optically coupling to the first carrier and adapted to modulate a signal at a second wavelength;
- 10 - a third transmitting transponder for optically coupling to a second carrier of the network and adapted to modulate a signal at the first wavelength;
- a first receiving transponder for optically coupling to the first carrier and adapted to demodulate a signal having the first wavelength;
- 15 - a second receiving transponder for optically coupling to the first carrier and adapted to demodulate a signal having the second wavelength;
- a third receiving transponder for optically coupling to the second carrier and adapted to demodulate a signal having the second wavelength;
- reconfigurable optical connections to selectively connect:
  - 20 • the optical transmitter either to the first transmitting transponder or to the third transmitting transponder;
  - the first receiving transponder to the third transmitting transponder;
  - the second receiving transponder to the optical receiver; and
  - the third receiving transponder either to the optical receiver or to the second transmitting transponder.
- 25     The receiving/transmitting module may further include:
  - a further optical transmitter to generate a signal including information to be transmitted in the network;
  - a further optical receiver to receive a signal including information transmitted in the network;
  - 30 - a fourth transmitting transponder optically coupled to the second carrier and adapted to modulate a signal at the second wavelength; and
  - a fourth receiving transponder optically coupled to the first carrier and adapted to demodulate a signal having the first wavelength;
  - 35     said reconfigurable optical connections selectively connecting:
    - the first receiving transponder either to the third transmitting transponder or

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to the further receiver;

- the fourth receiving transponder to the further receiver; and
- the further optical transmitter either to the second transmitting transponder or to the fourth transmitting transponder.

5 Preferably, the node is adapted to manage a predetermined set of wavelengths within a set of transmission wavelengths including a first and a second optical add/drop multiplexer optically coupling the receiving/transmitting module to said first and, respectively, second carrier to feed/extract said subset of wavelengths to/from said first and, respectively, second carrier, and to pass-through the remaining  
10 wavelengths of the set of transmission wavelengths.

The reconfigurable optical connections may include 2x2 switches or, alternatively, 1x2 and 2x1 switches.

The reconfigurable optical connections may include discrete switching components or, alternatively, an integrated switching matrix.

15 The reconfigurable optical connections may include optical switching components selectable in the group including:

- opto-mechanical switches;
- thermo-optical switches;
- magneto-optical switches;
- 20 - liquid crystal switches;
- semiconductor switches;
- electro-optical switches;
- micro-mechanical switches; and
- lithium niobate integrated circuit switches

25 The reconfigurable node preferably includes a control processing unit operatively connected to said receiving transponders and said transmitting transponders.

The reconfigurable node may include at least a further receiving/transmitting module which has substantially the same structure of said receiving/transmitting  
30 module and is adapted to operate with a different pair of wavelengths with respect to said receiving/transmitting module.

More details will become apparent from the following description, with reference to the accompanying drawings, in which:

35 Figures 1a, 1b, 1c show a network ring of a known type under normal condition, failure condition with a multiplex section shared protection and failure condition with a multiplex section shared protection – transoceanic application.

Figure 2 is a schematic representation of an optical communication network according to the present invention, operating under normal conditions and in which, by way of example, two transmission links are defined;

5     Figure 3 is a more detailed representation of one node of the network of Figure 2, including a switching unit comprising 2x2 switches and operating under normal conditions;

Figure 4 shows a switching unit comprising 1x2 and 2x1 switches used in the network of Figure 2 in place of the switching unit comprising 2x2 switches, operating under normal conditions;

10     Figure 5 shows a switching unit comprising an integrated switching circuit used in the network of Figure 2 in place of the switching unit comprising 2x2 switches, operating under normal conditions;

Figure 6 illustrates a sub-equipped node for the network of Figure 2, adapted to manage only one transmission link and including 2x2 switches;

15     Figure 7 shows a switching unit comprising 1x2 and 2x1 switches used in the network of Figure 6 in place of the switching unit comprising 2x2 switches, under normal operative conditions;

Figure 8 shows a switching unit comprising an integrated switching circuit used in the network of Figure 6 in place of the switching unit comprising 2x2 switches,  
20     under normal operative conditions;

Figure 9 illustrates the network of Figure 2 under a failure condition;

Figure 10 shows the reconfiguration of the node of Figure 3 when a failure occurs on its left-hand side;

25     Figure 11 shows the reconfiguration of the switching unit of Figure 4 when a failure occurs on the left-hand side of the node;

Figure 12 shows the reconfiguration of the switching unit of Figure 5 when a failure occurs on the left-hand side of the node;

Figure 13 shows the reconfiguration of the node of Figure 3 when a failure occurs on its right-hand side;

30     Figure 14 shows the reconfiguration of the switching unit of Figure 4 when a failure occurs on the right-hand side of the node; and

Figure 15 shows the reconfiguration of the switching unit of Figure 6 when a failure occurs on the right-hand side of the node.

35     Schematically shown in Figure 2 is an optical communication ring network 1 according to the present invention. Network 1 includes a first and a second optical fibre ring 2, 3 defining respective optical carriers having opposite transmission

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directions, and a plurality of nodes 20a-20f for adding and dropping optical signals, positioned along the first and the second ring 2, 3.

Network 1 is adapted to be used for both terrestrial transmissions and transoceanic transmissions. For long-haul transmissions, in particular for  
5 transoceanic transmissions, network 1 is preferably provided with line optical amplifiers and/or boosters and/or preamplifiers (not shown).

In the schematic representation of Figure 2, rings 2, 3 define an external and, respectively, an internal ring, having a counter-clockwise transmission direction and, respectively, a clockwise transmission direction. The nodes in network 1 have been  
10 chosen in number of six just by way of example and the present invention is identically applicable to networks including any number of nodes. Furthermore, the reference to connections comprising two optical fibers is to be considered merely as an example, the solution according to the invention being also suitable for utilization in ring networks in which the nodes are connected by a greater number of optical  
15 carriers.

Communication in network 1 is achieved according to a Wavelength Division Multiplexing (WDM) scheme using different channels at respective wavelengths on each ring. In particular, rings 2, 3 are adapted to convey optical signals in the transmission channels defined by a set of transmission wavelengths  $\lambda_1, \lambda_2, \dots, \lambda_N$   
20 within a predetermined wavelength transmission band.

Each of the nodes 20a-20f is adapted to manage a respective subset of wavelengths within the set of transmission wavelengths  $\lambda_1, \lambda_2, \dots, \lambda_N$  and to define bidirectional communications with one or more of the other nodes of network 1. Each pair of nodes arranged to mutually communicate splits network 1 into two  
25 complementary arc paths, at least one of which (identifiable as a "working path") allows bidirectional transmission between the two nodes under normal operative conditions (i.e. without failures), and the other (identifiable as a "protection path") allows to re-route such bidirectional transmission in the presence of a failure in the working path.

In greater detail, a generic pair of nodes arranged to mutually communicate has associated respective first and second wavelengths  $\lambda_x, \lambda_y$  for the exchange of data. Under normal operative conditions, on the working path defined by the considered pair of nodes, a bi-directional working link is established by transmitting optical signals at the first wavelength  $\lambda_x$  on the external ring 2 (in the counter-  
30 clockwise direction) and at the second wavelength  $\lambda_y$  on the internal ring 3 (in the clockwise direction). The second wavelength  $\lambda_y$  is not used on the external ring 2 and

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the first wavelength  $\lambda_x$  is not used on the internal ring 3. The second wavelength  $\lambda_y$  and the first wavelength  $\lambda_x$  can then be used on the external ring 2 and, respectively, on the internal ring 3, to provide optical protection, as hereinbelow described. For aim of clarity, the wavelengths which are used under normal operative conditions (i.e.  $\lambda_x$  on the external ring 2 and  $\lambda_y$  on the internal ring 3) to perform working links are identified with a "w" suffix ( $\lambda_{x,w}$ ,  $\lambda_{y,w}$ ), while the wavelengths which are adapted to be used for protection (i.e.  $\lambda_y$  on the external ring 2 and  $\lambda_x$  on the internal ring 3) are identified with a "p" suffix ( $\lambda_{x,p}$ ,  $\lambda_{y,p}$ ).

The first and the second wavelength  $\lambda_x$ ,  $\lambda_y$  can be used on the protection path associated to the considered pair of nodes to perform a further bidirectional working link between the first and the second node or to perform further bidirectional working links between other pairs of nodes (which may include one of the previously considered nodes), provided that those further working links do not overlap with each other and with the above considered one. Then, a generic pair of wavelengths  $\lambda_x$ ,  $\lambda_y$  defines a "logical ring", i.e. a virtual ring which may include many non-overlapping working links operating at  $\lambda_{x,w}$ ,  $\lambda_{y,w}$ . Protection wavelengths  $\lambda_{x,p}$ ,  $\lambda_{y,p}$ , not used under normal operative conditions, are shared among the different working links operating at  $\lambda_{x,w}$ ,  $\lambda_{y,w}$  (i.e. on the same logical ring). Overlapping working links can only be part of different logical rings and operate at different wavelengths.

The number of working links in a single logic ring depends on the client traffic pattern. For example with M nodes and N wavelengths (N even), in case of "hub traffic" (i.e. one node communicating with all the other nodes) a maximum of N protected working links can be established because each logical ring can support only two working links, while in case of "uniform traffic" (i.e. each node communicating only with its two adjacent) a maximum of MN/2 protected working links are available because each logical ring (i.e. each pair of wavelengths) can support M working links.

In the example of Figure 2, one working link is set up between node 20c and node 20f using the first working wavelength  $\lambda_{x,w}$  on the external ring 2 and the second working wavelength  $\lambda_{y,w}$  on the internal ring 3. Another working link is set up with the same wavelengths (and directions of propagation on the two rings 2, 3) between node 20d and node 20e. In this example, it is also possible to use the same wavelengths to set up a working link between node 20c and node 20d and between node 20e and node 20f, but it is not possible for example to set up a working link between node 20b and node 20e because it will overlap with the ring arcs already used by the previous links.

As later described in greater detail, each of nodes 20a-20f provides optical add/drop/bypass functions for each wavelength within the wavelength transmission band on both the external and internal fiber rings 2, 3, together with optical amplification and regeneration (if necessary).

5 Figure 3 shows the structure of a generic node 20i of network 1, in particular of one node operating at wavelengths  $\lambda_x$  and  $\lambda_y$ .

Node 20i includes a first and a second optical add/drop multiplexer (OADM) 4, 5 and a receiving/transmitting module 6 comprising:

- a first and a second transmitter  $Tx_1, Tx_2$ ;
- 10 - a first and a second receiver  $Rx_1, Rx_2$ ;
- a first, a second, a third and a fourth transmitting transponder  $TxT_1(\lambda_x), TxT_1(\lambda_y), TxT_2(\lambda_x), TxT_2(\lambda_y)$ ;
- a first, a second, a third and a fourth receiving transponder  $RxT_1(\lambda_x), RxT_1(\lambda_y), RxT_2(\lambda_x), RxT_2(\lambda_y)$ ;
- 15 - a switch unit 15; and
- a central processing unit (CPU) 16.

The first and the second OADM 4, 5 are adapted to insert into rings 2, 3, and to extract from rings 2, 3, signals at the working and protection wavelengths associated to node 20i (i.e.  $\lambda_x$  and  $\lambda_y$ ) and to by-pass the other wavelengths of the set of transmission wavelengths. If required, OADMs 4, 5 may perform other functions within the wavelength transmission band, such as regeneration, performance monitoring, etc. In greater detail, the first OADM 4 is coupled to the fiber of the external ring 2 for dropping signals from, and adding signals into, the external ring 2, and the second OADM 5 is coupled to the fiber of the internal ring 3 for dropping signals from, and adding signals into, the internal ring 3. OADMs 4 and 5 may be, for example, of the type Pirelli Optical Systems OADM/P4-R1 (WaveMux6400 product family).

Transmitters  $Tx_1, Tx_2$  and receivers  $Rx_1, Rx_2$  represent the client access points for the input and the output of information. In particular, transmitters  $Tx_1, Tx_2$  allows the input of information addressed to two different receivers connected to network 1. The input of information by transmitters  $Tx_1, Tx_2$  may be performed at wavelengths not included in the transmission wavelength band of network 1, since the transmitting transponders TxTs are in charge to provide the signals with the correct wavelength, i.e. with the first wavelength  $\lambda_x$  or the second wavelength  $\lambda_y$ .  $Tx_1, Tx_2$  may be, for example, for example a standard Sonet OC-48/SDH STM-16 terminal (produced for example by Nortel). Different bit rate terminals can be used provided that the

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transmitting transponders are compatible.

Receivers  $Rx_1$ ,  $Rx_2$  allow the output of information coming from two different transmitters connected to network 1. Receivers  $Rx_1$ ,  $Rx_2$  may be adapted to receive signals at wavelengths not included in the transmission wavelength band of network 1, since receiving transponders  $RxTs$  are in charge to provide the signals coming from the network 1 with a wavelength adapted for reception receivers  $Rx_1$ ,  $Rx_2$ .  $Rx_1$ ,  $Rx_2$  may be, for example, a standard Sonet OC-48/SDH STM-16 terminal (produced for example by Nortel). Different bit rate terminals can be used provided that the receiving transponders are compatible.

10 The first and the second transmitting transponder  $TxT_1(\lambda_x)$ ,  $TxT_1(\lambda_y)$  are optically coupled to the external ring 2 by means of the first OADM 4 and are adapted to feed signals at wavelength  $\lambda_x$  and, respectively,  $\lambda_y$ , to the external ring 2; the third and the fourth transmitting transponder  $TxT_2(\lambda_x)$ ,  $TxT_2(\lambda_y)$  are optically coupled to the internal ring 3 by means of the second OADM 5 and are adapted to feed signals at wavelength  $\lambda_x$  and, respectively,  $\lambda_y$ , to the internal ring 3.

15 In detail, each transmitting transponder  $TxT_1(\lambda_x)$ ,  $TxT_1(\lambda_y)$ ,  $TxT_2(\lambda_x)$ ,  $TxT_2(\lambda_y)$  may be of a type adapted to receive an optical signal from switch unit 15, to transform it into electrical format for processing and to newly transform it into optical format for transmission, with a predetermined wavelength within the wavelength band. Transmitting transponders of this type are, for example, Pirelli Optical Systems WCM/F-xxx (WaveMux6400 product family, xxx = output wavelength code). Alternatively, the transmitting transponder may be completely optical devices (for example based on SOAs, Semiconductor Optical Amplifiers) managing information associated to the signal, for example managing a pilot tone over-modulating the optical wavelength carrying the signal.

20 Processing, in this case, includes providing the transmitted signals with information for protection purposes (e.g. channel identifier, performance monitoring, protection protocol) as a channel overhead. This information is not part of the client payload and are added to the signal by the transmitting transponders under the supervision of the CPU. For example the Pirelli Optical Systems WCM/F-xxx unit is able to add an overhead channel to the client payload to transport the signalling information. A similar technique, but operating at the multiplex section level, is used in the Sonet/SDH protocol at the transmitting side (e.g. channel overhead, multiplex section overhead with B1 monitor byte and K1/K2 APS bytes).

35 The first and the second receiving transponder  $RxT_1(\lambda_x)$ ,  $RxT_1(\lambda_y)$  are optically coupled to the external ring 2 by means of the first OADM 4 and are adapted to

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receive signals at wavelength  $\lambda_x$  and, respectively,  $\lambda_y$ ; the third and the fourth receiving transponder  $RxT_2(\lambda_x)$ ,  $RxT_2(\lambda_y)$  are optically coupled to the internal ring 3 by means of the second OADM 5 and are adapted to receive signals at wavelength  $\lambda_x$  and, respectively,  $\lambda_y$ .

5 In detail, each receiving transponder  $RxT_1(\lambda_x)$ ,  $RxT_1(\lambda_y)$ ,  $RxT_2(\lambda_x)$ ,  $RxT_2(\lambda_y)$  may be of the type adapted to receive an optical signal from rings 2, 3, to transform it into electrical format for processing and to newly transform it into optical format, with a predetermined wavelength adapted for reception by a corresponding receiver  $Rx_1$ ,  $Rx_2$ . Receiving transponders of this type are, for example, Pirelli Optical Systems  
10 RXT-DM/F (WaveMux6400 product family). Alternatively, the receiving transponders, like the transmitting transponders, may be completely optical devices (for example based on SOAs, Semiconductor Optical Amplifiers) managing information associated to the signal, for example to a pilot tone over-modulating the optical wavelength carrying the signal.

15 Processing, in this case, includes extracting from the received signals the information previously inserted as channel overhead by the corresponding TXT at the transmitting node for protection purposes (e.g. channel identifier, performance monitoring, protection protocol). For example the Pirelli Optical Systems RXT-DM/F unit is able to extract an overhead channel from the received signal to process the  
20 signalling information. A similar technique, but operating at the multiplex section level, is used in the Sonet/SDH protocol at the receiving side (e.g. channel overhead, multiplex section overhead with B1 monitor byte and K1/K2 APS bytes).

CPU 16 is in charge to communicate with the transmitting and receiving transponders TxTs, RxTs in order to provide or to process the information related to  
25 the working links (link signalling), to check the operative conditions of the related working links and to control switch unit 15 in accordance to the detected operative conditions. Link signalling must include channel identification information which can be implemented for example either by means of a pilot tone over-modulating the optical wavelength carrying the signal or by using a TDM (Time Division Multiplexing)  
30 frame structure including the signal channels together with an extra channel for link signalling transmission. Logical connections between CPU 16 and its controlled units are represented in Figure 3 by means of dashed lines.

Switch unit 15 is adapted to provide the optical switching facilities implementing the protection layout as disclosed in this invention, by selectively connecting  
35 transmitters TxS and receivers RxS to transmitting transponders TxTs and receiving transponders RxTs. As shown in Figure 3, switch unit 15 may comprise a first, a

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second, a third and a fourth 2x2 optical switch 22-25 driven by CPU 16 through appropriate control logics (not shown). Optical switches 22-25 may be, for example, 2x2 optomechanical switches (e.g. of the type produced by JDS FITEI, INC., 570 Heston Drive, Napsan, Ontario (CA) or of the type produced by E-TEK DYNAMICS, INC., 1885 Lundy Ave., San Jose, CA (USA)). Optical switches 22-25 are connected as follows:

- the first switch 22 has a first input 22a coupled to the first transmitter  $Tx_1$ , a second input 22b, a first output 22c coupled to the first transmitting transponder  $TxT_1(\lambda_x)$  and a second output 22d coupled to the third transmitting transponder  $TxT_2(\lambda_x)$ ;
- the second switch 23 has a first input 23a coupled to the fourth receiving transponder  $RxT_2(\lambda_y)$ , a second input 23b coupled to the second receiving transponder  $RxT_1(\lambda_y)$ , a first output 23c coupled to the first receiver  $Rx_1$  and a second output 23d;
- the third switch 24 has a first input 24a coupled to the second output 23d of the second switch 23, a second input 24b coupled to the second transmitter  $Tx_2$ , a first output 24c coupled to the second transmitting transponder  $TxT_1(\lambda_y)$  and a second output 24d coupled to the fourth transmitting transponder  $TxT_2(\lambda_y)$ ; and
- the fourth switch 25 has a first input 25a coupled to the third receiving transponder  $RxT_2(\lambda_x)$ , a second input 25b coupled to the first receiving transponder  $RxT_1(\lambda_x)$ , a first output 25c coupled to the second input 22b of the first switch 22 and a second output 25d coupled to the second receiver  $Rx_2$ .

Each switch 22-25 can operate in a bypass status (typically used under normal conditions), in which the first input is coupled to the first output and the second input is coupled to the second output, or in a switched status (typically used in case of failure), in which the first input is coupled to the second output and the second input is coupled to the first output.

The architecture of Figure 3 is modular and can be applied for each logical ring in which the node acts as a link termination. In other words, node 20i may include a plurality of modules 6, each for managing a different pair of wavelength. In this case, the wavelengths assigned to each logical ring are separately added/dropped by the two OADMs 4, 5 and processed separately by a corresponding module 6.

It has to be noted that the functional layout of the node described above can be physically implemented in different ways, for example integrating the CPU 16 or the transponders 6-13 inside the switch unit 15.

Switch unit 15 is over-dimensioned for the switching requirements of node 20i

and it defines, in case of failure, some interconnections which are not operatively used. For example, while the first receiving transponder  $RxT_1(\lambda_w)$  is connected to the second receiver  $Rx_2$  under normal operative conditions, no connection is needed for the first receiving transponder  $RxT_1(\lambda_w)$  in case of failure on the external ring 2 on the right-hand side of node 20i (since no signal is received from this side). Taking into consideration this over-dimensioning of the switch unit functionality, it is possible to use, in place of the 2x2 switch type unit, other unit architectures which allow to optimize the number of interconnections in relation to the functional requirements. The interconnection requirements in node 20i under both normal and failure conditions (i.e. for working and protection) is summarized in the following table:

	$Rx_1$	$Rx_2$	$TxT_1(\lambda_x)$	$TxT_1(\lambda_y)$	$TxT_2(\lambda_x)$	$TxT_2(\lambda_y)$
$Tx_1$			W		P	
$Tx_2$				P		W
$RxT_1(\lambda_x)$		W				
$RxT_1(\lambda_y)$	P			P		
$RxT_2(\lambda_x)$		P			P	
$RxT_2(\lambda_y)$	W					

W=Working P=Protection

Figure 4 shows a switch unit 15' including 1x2 and 2x1 optomechanical switches, to be used in place of switch unit 15. Switch unit 15' implements the required interconnection functionality and can be, for example, of the type produced by JDS FITEL, INC., 570 Heston Drive, Nepean, Ontario (CA) or of the type produced by E-TEK DYNAMICS, INC., 1885 Lundy Ave., San Jose, CA (USA). In Figure 4, for reason of clarity, the input connections and the output connections of switch unit 15' are grouped on the left side and, respectively, on the right side of switch unit 15'. In detail, switch unit 15' include:

- a first switch 31 of the 1x2 type, having its input coupled to the first transmitter  $Tx_1$  and its first output coupled to the first transmitting transponder  $TxT_1(\lambda_w)$ ;
- a second switch 32 of the 2x1 type, having its first input coupled to the second output of the first switch 31 and its output coupled to the third transmitting transponder  $TxT_2(\lambda_w)$ ;
- a third switch 33 of the 1x2 type, having its input coupled to the third receiving transponder  $RxT_2(\lambda_x)$  and its first output coupled to the second input of the second switch 32;
- a fourth switch 34 of the 2x1 type, having its first input coupled to the second

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- output of the third switch 33, its second input coupled to the first receiving transponder  $RxT_1(\lambda_x)$  and its output coupled to the second receiver  $Rx_2$ ;
- a fifth switch 35 of the 2x1 type, having its first input coupled to the fourth receiving transponder  $RxT_2(\lambda_y)$  and its output coupled to the first receiver  $Rx_1$ ;
  - 5 - a sixth switch 36 of the 1x2 type, having its input coupled to the second receiving transponder  $RxT_1(\lambda_y)$  and a first output coupled to the second input of the fifth switch 35;
  - a seventh switch 37 of the 2x1 type, having its first input coupled to the second output of the sixth switch 36 and its output coupled to the second transmitting
  - 10 transponder  $TxT_1(\lambda_y)$ ; and
  - an eighth switch 38 of the 1x2 type, having its input coupled to the second transmitter  $Tx_2$ , its first output coupled to the second input of the seventh switch 37 and its second output coupled to the fourth transmitting transponder  $TxT_2(\lambda_y)$ .

15 In Figure 4, connections which are operative under normal conditions are shown with a continuous line, while connections which are not used under normal condition are represented with a dashed line.

In a further possible embodiment shown in Figure 5, the switch unit, here indicated with 15", includes a lithium niobate ( $LiNbO_3$ ) integrated switching matrix, in which interconnections among input and outputs reproduce the layout of the switch unit 15' of Figure 4. In particular, switch unit 15" includes four 1x2 switches each comprising:

- an input waveguide,
- a Y-shaped branching waveguide having one input arm connected to input waveguide and having two output arms, and
- 25 - a first and a second output waveguides each connected to one of the output arms of the branching waveguide,

and four 2x1 switches each comprising:

- a first and a second input waveguide,
- a Y-shaped branching waveguide having two input arms connected to the input waveguide and one output arm, and
- 30 - a first output waveguide connected to the output arm of the branching waveguide.

Switch unit 15" also includes electrodes (not shown) formed on the surface of substrate in correspondence of the Y-shaped branching waveguides and adapted to produce the switching action between the two arms of the Y.

35 In detail, switch unit 15" includes:

- a first switch 41 (1x2) having its input waveguide coupled to the first transmitter

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$Tx_1$  and its first output waveguide coupled to the first transmitting transponder  $TxT_1(\lambda_x)$ ;

- a second switch 42 (2x1) having its first input waveguide coupled to the second output waveguide of the first switch 41 and its output waveguide coupled to the third transmitting transponder  $TxT_2(\lambda_y)$ ;
- a third switch 43 (1x2) having its input waveguide coupled to the third receiving transponder  $RxT_2(\lambda_x)$  and its first output waveguide coupled to the second input waveguide of the second switch 42;
- a fourth switch 44 (2x1) having its first input waveguide coupled to the second output waveguide of the third switch 43, its second input waveguide coupled to the first receiving transponder  $RxT_1(\lambda_y)$  and its output waveguide coupled to the second receiver  $Rx_2$ ;
- a fifth switch 45 (2x1) having its first input waveguide coupled to the fourth receiving transponder  $RxT_2(\lambda_y)$  and its output waveguide coupled to the first receiver  $Rx_1$ ;
- a sixth switch 46 (1x2) having its input waveguide coupled to the second receiving transponder  $RxT_1(\lambda_y)$  and its first output waveguide coupled to the second input waveguide of the fifth switch 45;
- a seventh switch 47 (2x1) having a first input waveguide coupled to the second output waveguide of the sixth switch 46 and an output waveguide coupled to the second transmitting transponder  $TxT_1(\lambda_y)$ ; and
- an eighth switch 48 (1x2) having an input waveguide coupled to the second transmitter  $Tx_2$ , a first output waveguide coupled to the second input waveguide of the seventh switch 47 and a second output waveguide coupled to the fourth transmitting transponder  $TxT_2(\lambda_y)$ .

In Figure 5, connections which are operative under normal conditions are shown with a continuous line, while connections which are not used under normal condition are represented with a dashed line.

The use of an integrated switching matrix offers several advantages over a discrete components switching matrix. In particular:

- opto-mechanical switch units 15 and 15' are more cumbersome than the integrated switch unit 15"; for example, a typical 2x2 opto-mechanical switch may occupy a surface of about 48x18 mm<sup>2</sup>, and four switches are needed to form the switch unit 15, while the integrated switch unit 15" may occupy an area of about 4x85 mm<sup>2</sup>;
- integrated switch unit 15" has response times lower than opto-mechanical switch

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units 15 and 15'; in fact, integrated switch unit 15" allows response times of about 1 ms, while opto-mechanical switch units 15 and 15' have typical response times of about 5-10 ms;

- the use of a single integrated device in place of four 2x2 switches or eight 1x2 and 2x1 switches allows to simplify the piloting electronic circuit;
- integrated switch unit 15' is cheaper than opto-mechanical switch units 15 and 15'.

Alternatively to the optomechanical switch units 15 and 15' and to the lithium niobate integrated switch unit 15", other types of optical switch units may be used, including either a discrete components switching matrix or an integrated switching matrix, for example including thermo-optical switches, magneto-optical switches, liquid crystal switches, SOA (Semiconductor Optical Amplifier) switches, electro-optical switches and micro-mechanical switches (MEMS).

The node structure previously described is adapted to manage two working links on the same logical ring. Anyway, if the client traffic pattern requires only one working link to be terminated at a generic node, this node may be sub-equipped. This situation is depicted in Figure 6, where a generic one-link node 20j adapted to manage a single working link in its left-hand side is shown under normal operative conditions.

Node 20j differs from the node 20i of Figure 3 in that the second transmitter  $Tx_2$ , the second receiver  $Rx_2$ , the first receiving transponder  $RxT_1(\lambda_x)$  and the fourth transmitting transponder  $TxT_2(\lambda_y)$  of node 20i are absent, and in that it includes a switch unit 115 which does not comprise the third and the fourth switch 24, 25 of switch unit 15. Therefore, differently from the architecture of Figure 3, the third receiving transponder  $RxT_2(\lambda_x)$  is directly coupled to the second input 22b of the first switch 22 and the second output 23d of the second switch 23 is directly coupled to the second transmitting transponder  $TxT_1(\lambda_y)$ . The single working link managed by node 20j includes signals sent by node 20j to another node at the working wavelength  $\lambda_{x,w}$  on the external ring 2 and signals received by node 20j from the other node at the working wavelength  $\lambda_{y,w}$  on the internal ring 3. Protection wavelengths  $\lambda_{x,p}$  and  $\lambda_{y,p}$  are managed in the same way as described before for the two-link node.

Figure 7 shows an alternative switch unit 115' for a one-link node to be used in place of switch unit 115. Switch unit 115' includes 1x2 and 2x1 optomechanical switches of the same type as those of switch unit 15' and implements the interconnection functionality required for node 20j, omitting the unused

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interconnections. For sake of clarity, input connections and output connections of switch unit 115' are grouped on the left side and, respectively, on the right side of switch unit 115'.

Switch unit 115' includes a first switch 131 (1x2), a second switch 132 (2x1), a third switch 135 (2x1) and a fourth switch 136 (1x2) respectively equivalent to switches 31, 32, 35 and 36 of switch unit 15' (Figure 4) and differs from switch unit 15' in that switches 33, 34, 37 and 38 of switch unit 15' are absent.

In detail, switch unit 115' include:

- a first switch 131 of the 1x2 type, having its input coupled to the first transmitter  $Tx_1$  and its first output coupled to the first transmitting transponder  $TxT_1(\lambda_x)$ ;
- a second switch 132 of the 2x1 type, having its first input coupled to the second output of the first switch 131, its second input coupled to the third receiving transponder  $RxT_2(\lambda_y)$  and its output coupled to the third transmitting transponder  $TxT_2(\lambda_x)$ ;
- a third switch 135 of the 2x1 type, having its first input coupled to the fourth receiving transponder  $RxT_2(\lambda_y)$  and its output coupled to the first receiver  $Rx_1$ ; and
- a fourth switch 136 of the 1x2 type, having its input coupled to the second receiving transponder  $RxT_1(\lambda_y)$ , a first output coupled to the second input of the third switch 135 and a second output coupled to the second transmitting transponder  $TxT_1(\lambda_y)$ .

In Figure 7, connections which are operative under normal conditions are shown with a continuous line, while connections which are not used under normal condition are represented with a dashed line.

Figure 8 shows an integrated optics switch unit 115" having the same switching architecture of switch unit 115' of Figure 7, but realized using the same technology of switch unit 15" of Figure 5, i.e. lithium niobate ( $LiNbO_3$ ) integrated circuit technology. Switch unit 115" includes a first switch 141 (1x2), a second switch 142 (2x1), a third switch 145 (2x1) and a fourth switch 146 (1x2) performing the same signal routing as the corresponding switches of switch unit 115' (figure 7).

Alternatively, switch units 115, 115' and 115" may include switches selectable in the set comprising thermo-optical switches, magneto-optical switches, liquid crystal switches, SOA (Semiconductor Optical Amplifier) switches, electro-optical switches and micro-mechanical switches (MEMS).

Network 1 operates as follows.

When a link between a first and a second node of the network 1 has to be

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established, a generic pair of first and second wavelengths  $\lambda_x, \lambda_y$  is chosen within the wavelength band. A working link is then set up between the two nodes by connecting the first transmitter  $Tx_1$  of the first node to the second receiver  $Rx_2$  of the second node using the first wavelength  $\lambda_x$  on the external ring 2, and by connecting the second transmitter  $Tx_2$  of the second node to the first receiver  $Rx_1$  of the first node using the second wavelength  $\lambda_y$  on the internal ring 3, on a same working arc path. As previously described, other working links may be set up in the protection path of the two considered nodes, provided that the working path used by each working link is non-overlapping with other working paths used by other working links using the same wavelengths. In the case here considered, the second wavelength  $\lambda_y$  on the external ring 2 and the first wavelength  $\lambda_x$  on the internal ring 3 are not used under normal operative conditions, and are reserved for optical protection (i.e. are reserved for use in case of failure).

Each working link is under control of the two nodes at the end of the link itself. This means that, for a working link operating at working wavelengths  $\lambda_{x,w}, \lambda_{y,w}$ , the two nodes at the end of this link must provide the add/drop functions on working wavelengths  $\lambda_{x,w}$  and  $\lambda_{y,w}$  to/from the set of transmission wavelengths  $\lambda_1, \dots, \lambda_N$ . Moreover, all the required monitoring functions on the transmitted signals (e.g. optical power level, channel identifier, BER performance, etc.) have to be carried out at these terminating nodes. It has to be noted that the nodes not involved in communications on working wavelengths  $\lambda_{x,w}$  and  $\lambda_{y,w}$  do not provide any function on them, and these wavelengths are directly bypassed. Each node at the end of a working link using wavelengths  $\lambda_{x,w}$  and  $\lambda_{y,w}$  must also have the control on the protection wavelengths  $\lambda_{x,p}$  and  $\lambda_{y,p}$ , being these wavelengths shared for protection among all the working links of the corresponding logical ring. The other nodes (i.e. the nodes external this logical ring) are not required to perform any operation on  $\lambda_{x,p}$  and  $\lambda_{y,p}$ , and these wavelengths are simply bypassed in these nodes. As a general rule, the nodes not included in a logical ring (i.e. not terminating a generic working link on this logical ring) can be completely transparent to the wavelengths associated to the logical ring.

In the example of Figure 2, the working link between node 20c and node 20f operating on working wavelengths  $\lambda_{x,w}$  and  $\lambda_{y,w}$  is under control of these two nodes, and the working link between node 20d and 20e operating on the same wavelengths is under control of these two last nodes. Each of the nodes 20c, 20d, 20e and 20f has also the control on the protection wavelengths  $\lambda_{x,p}, \lambda_{y,p}$  associated to the

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corresponding logical ring, in order to have access to the shared protection resource.

Nodes 20a and 20b cannot be part of the logical ring operating at working wavelengths  $\lambda_{x,w}$ ,  $\lambda_{y,w}$  and may define termination nodes of working links at wavelengths different from  $\lambda_{x,w}$ ,  $\lambda_{y,w}$ . Therefore, nodes 20a and 20b do not perform  
 5 any action on working wavelengths  $\lambda_{x,w}$ ,  $\lambda_{y,w}$  and protection wavelengths  $\lambda_{x,p}$ ,  $\lambda_{y,p}$ , even if they may be required to provide optical amplification on the set of transmission wavelengths  $\lambda_1, \dots, \lambda_N$ . Furthermore, each node may be required to provide functions like regeneration or monitoring on the bypassed wavelengths, in order to allow a constant performance control of the set of transmission wavelengths  
 10  $\lambda_1, \lambda_2, \dots, \lambda_N$  over the entire ring network. Indeed, under failure conditions, these nodes have not to provide any reconfiguration action on the channels carried by the bypassed wavelengths.

With reference to Figure 3, the signal flow inside the generic node 20i, under normal operative conditions, is as follows.

15 In reception, the first and the second OADM 4, 5 drop the wavelengths of the logical rings to be managed. All the other wavelengths may be directly bypassed to the node output without any processing. In greater detail, the first OADM 4 drops from the set of transmission wavelengths  $\lambda_1, \dots, \lambda_N$  on the external ring 2 both the working and protection wavelengths  $\lambda_{x,w}$  and  $\lambda_{y,p}$  (and possibly working and protection  
 20 wavelengths of other logical rings to be managed), while the second OADM 5 drops from the set of transmission wavelengths  $\lambda_1, \dots, \lambda_N$  on the internal ring 3 both the working and protection wavelengths  $\lambda_{y,w}$  and  $\lambda_{x,p}$  (and possibly working and protection wavelengths of other logical rings to be managed). Wavelengths  $\lambda_{x,w}$ ,  $\lambda_{y,p}$ ,  $\lambda_{y,w}$  and  $\lambda_{x,p}$  are sent directly to the respective receiving transponders  $RxT_1(\lambda_x)$ ,  $RxT_1(\lambda_y)$ ,  
 25  $RxT_2(\lambda_y)$  and  $RxT_2(\lambda_x)$ , where, after conversion in electric format, information related to the link (link signalling) is extracted and sent to the CPU 16 for processing. After processing, wavelengths  $\lambda_{x,w}$ ,  $\lambda_{y,p}$ ,  $\lambda_{y,w}$  and  $\lambda_{x,p}$  are newly converted in optical format.

The first working wavelength  $\lambda_{y,w}$  is then routed through switch unit 15 to the first receiver  $Rx_1$ , and the second working wavelength  $\lambda_{x,w}$  is routed through switch  
 30 unit 15 to the second receiver  $Rx_2$ . The first and the second protection wavelengths  $\lambda_{x,p}$  and  $\lambda_{y,p}$  are by-passed through switch unit 15 to the third transmitting transponder  $TxT_2(\lambda_x)$  and, respectively, to the second transmitting transponder  $TxT_1(\lambda_y)$ , from where they are fed to the internal ring 3 and, respectively, to the external ring 2 by the second OADM 5 and, respectively, the first OADM 4. Signalling information  
 35 carried by the protection wavelengths is left unchanged since no protection is

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required at the moment on the two working channels.

Signals generated by the first transmitter  $Tx_1$  are routed through switch unit 15 to the first transmitting transponder  $TxT_1(\lambda_x)$  for transmission on the first working wavelength  $\lambda_{x,w}$ , and signals generated by the second transmitter  $Tx_2$  are routed through switch unit 15 to the fourth transmitting transponder  $TxT_2(\lambda_y)$  for transmission on the second working wavelength  $\lambda_{y,w}$ . In the first and the fourth transmitting transponder  $TxT_1(\lambda_x)$ ,  $TxT_2(\lambda_y)$ , appropriate information (link signalling, channel identifier) generated by CPU 16 is added (for example by using bytes k1 and k2 as recommended in ITU-T standard) to signals on the first working wavelength  $\lambda_{x,w}$  and, respectively, on the second working wavelength  $\lambda_{y,w}$ . These wavelengths are then sent respectively to the external and internal rings 2, 3 by OADMs 4, 5.

Identical operations are performed in each receiving/transmitting module included in node 201, for corresponding pairs of wavelengths that have to be managed by this node.

When a failure occurs, reconfiguration takes place in all those, and only those, logical rings including at least a working link whose transmission is affected by the failure. It is intended that the failure can be everything affecting the transmission between two nodes, therefore not only a fiber cut but also a failure in a node device such as a OADM or a transponder. Reconfiguration in a logical ring is performed independently from reconfiguration in the other logical rings. In particular, for each working link affected by the failure, reconfiguration takes place only at the pair of nodes terminating the link, while the nodes interposed between these terminating nodes do not perform any action to restore the failed link.

As a consequence of a failure on the generic working link operating at the working wavelengths  $\lambda_{x,w}$ ,  $\lambda_{y,w}$ , the two nodes terminating the working link detect the failure condition (in the way hereinbelow described) and run the reconfiguration process by switching the transmission on the respective protection arc path using the protection wavelengths  $\lambda_{x,p}$ ,  $\lambda_{y,p}$ . In practice, signals previously transmitted at the first working wavelength  $\lambda_{x,w}$  on the external ring 2 are switched at the first protection wavelength  $\lambda_{x,p}$  on the internal ring 3, while signals previously transmitted at the second working wavelength  $\lambda_{y,w}$  on the internal ring 3 are switched at the second protection wavelength  $\lambda_{y,p}$  on the external ring 2.

The working link between the two nodes is consequently re-routed on the respective protection path by using the protection wavelengths  $\lambda_{x,p}$ ,  $\lambda_{y,p}$ , if necessary through nodes which are terminating other working links on the same logical ring.

These last nodes do not have to perform any action as a consequence of the reconfiguration process performed by the nodes terminating the working link affected by the failure, but must be aware of the presence of a signal carried by the protection wavelengths in order to know that the protection resource has been taken by another working link of the same logical ring. Therefore, as a consequence of the protection operations performed on the failed working link, all the other working links of the same logical ring become unprotected. This situation persists until the failure has been repaired and the transmission previously switched on the protection path has been restored on the original working link. Moreover, nodes which terminate working links sharing the same protection resource of the failed one (i.e. the working links of the same logical ring) must have the protection mechanism inhibited until normal conditions are restored.

Figure 9 depicts a situation in which a failure occurs in the ring network of Figure 2 between nodes 20a and 20b. According to the above, nodes 20a and 20b do not perform any action in response to the failure because, in the particular condition disclosed, they are not terminating nodes of a working link affected by the failure.

The hereinbelow described sequence of operations for the failure detection and signalling performed by nodes 20c and 20f is to be considered only as an example. Different sequence of operations may alternatively be used, without depart from the scope of the present invention, all leading to a transitory condition at the end of which nodes 20c and 20f are both reconfigured.

Supposing that the failure affects only the transmission from node 20f to node 20c (along the internal ring 3), while the opposite transmission (along the external ring 2) is still operative, node 20c detects the absence of signals or a signal quality degradation (corresponding, for example, to a BER over a predetermined threshold) at the second working wavelength  $\lambda_{yw}$  on the fourth receiving transponder  $RxT_2(\lambda_y)$  and, consequently, its CPU 16 operates a reconfiguration of its switch unit 15 (as hereinbelow described with reference to Figure 10) in order to switch the transmission (in the manner described below) on the protection path. Before reconfiguration takes place, node 20c sends node 20f a failure message preferably along both the external ring 2 (in the counter-clockwise direction) and the internal ring 3 (in the clockwise direction) and preferably by using the protection wavelengths  $\lambda_{yp}$  and  $\lambda_{yp}$  to inform node 20f of the new situation.

In the preferred case of the bidirectional message transmission, node 20f receives the message from both the external ring 2 and the internal ring 3 (for

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example at the protection wavelengths  $\lambda_{x,p}$  and  $\lambda_{y,p}$ ) and reacts by performing the reconfiguration of its switch unit 15 (as shown in Figure 13), consequently switching the transmission on the respective protection path.

On the other hand, if the failure affects only the transmission from node 20c to node 20f (along the external ring 2), a similar sequence of operations is performed starting from node 20f.

Alternatively, if both the transmission directions are affected by the failure, the first one between nodes 20c and 20f becoming aware of the absence of signals or of a signal quality degradation sends the other node the failure message (preferably along both the external ring 2 and the internal ring 3 and preferably by using the protection wavelengths  $\lambda_{x,p}$  and  $\lambda_{y,p}$ ) and subsequently operates a reconfiguration of its switch unit 15. The other node realizes the presence of a failure in the considered link either as a consequence of the detection of the absence of signals or of a signal quality degradation, or as a consequence of the reception of the failure message from the first node (and only from one direction, in the preferred case of the bidirectional message transmission) and, in its turn, sends a failure message to the first node and operates a reconfiguration of its switch unit 15.

At the end of the above transitory condition, signals transmitted between nodes 20c and 20f are carried on the respective protection path. Nodes 20d and 20e, which, in the example of Figure 2, are the termination nodes of another working link in the same logical ring, are informed of the new situation by checking the status of the channel carried by the protection wavelengths bypassed (i.e. by reading the failure message), and they consequently inhibit their protection mechanism.

When the failure has been repaired, the normal condition can be restored on each affected logical ring by resetting the switching layouts at the terminating nodes of the failed working links so as to re-route such links on their original working path. On the generic logical ring, all the link terminating nodes not previously affected by the failure are informed of the release of the shared protection capacity by checking the status of the channel carried by the protection wavelengths (which are now unused). As a consequence, these link terminating nodes re-enable their protection mechanism.

Figure 10 depicts the situation in which a failure occurs on a working link defined by the generic node 20i (together with a further node not shown), in particular a failure on the left-hand side of node 20i. Node 20i is informed of the failure condition by detecting, at the fourth receiving transponder  $RxT_2(\lambda_y)$ , the absence of signals, or a signal quality degradation (like a BER over a predetermined threshold),

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or the reception of a failure message (as previously described). CPU 16 consequently generates an appropriate failure message to be sent to the other terminating node of the working link, preferably along both the external ring 2 and the internal ring 3. CPU 16 preferably feeds this failure message to the second  
5 transmitting transponder  $TxT_1(\lambda_y)$  for transmission at the second protection wavelength  $\lambda_{y,p}$  and to the third transmitting transponder  $TxT_2(\lambda_x)$  for transmission at the first protection wavelengths  $\lambda_{x,p}$ . CPU 16 subsequently operates the reconfiguration of switch unit 15, by reconfiguring switches 22 and 23 from the bypass status to the switched status in order to bypass the failed working path and  
10 re-route the transmission towards the other node of the failed working link on the respective protection path.

In the new node configuration, the first transmitter  $Tx_1$  is connected to the third transmitting transponder  $TxT_2(\lambda_x)$  and the corresponding signals are then sent on the internal ring 3 in clockwise direction, while the first receiver  $Rx_1$  is connected to the  
15 second receiving transponder  $RxT_1(\lambda_y)$  and the signals are then received from the external ring 2 in counter-clockwise direction. If the considered node includes a switch unit 15' (1x2 and 2x1 switches) or a switch unit 15'' (integrated optics) in place of switch unit 15 (2x2 switches), the reconfigured status of the corresponding switch unit is as shown in Figure 11 and, respectively, in Figure 12.

20 The node at the other end of the affected link performs the same operations, after receiving a failure message from the other node, or after detecting the absence of signals or a signal quality degradation at its first receiving transponder  $RxT_1(\lambda_x)$ . The working link between the two nodes is consequently re-routed on the protection path associated to the working link. Both the reconfigured nodes have also to update  
25 the signalling information (generated by the respective CPUs and added to the transmitted signals in the respective transmitting transponders  $TxTs$ ) carried by the protection wavelengths  $\lambda_{x,p}$ ,  $\lambda_{y,p}$  in order to inform all the other nodes on the same logical ring that the shared resource is at present used by the two considered nodes.

When the failure has been repaired, both the nodes at the end of the affected  
30 link can be restored to the normal operative condition of Figure 3, thus releasing the shared protection resource.

In nodes including more than one receiving/transmitting module 6, the described protection mechanism operates independently for each module 6.

Figures 13-15 depicts the situation in which a failure occurs on the right-hand  
35 side of the generic node 201. The reconfiguration process is very similar to the one referred to the left-hand side failure and is not here described.

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It is intended that, without depart from the scope of the present invention, the architecture of the nodes may be arranged so that, in the absence of failures, protection wavelengths  $\lambda_{x,p}$  on the internal ring 3 and  $\lambda_{y,p}$  on the external ring 2 may be used to transport low-priority in the same direction as the other wavelengths on

5 the same ring.

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## CLAIMS

1. Autoprotected optical communication ring network, including a first and a second optical carrier (2, 3) having opposite transmission directions and a plurality of  
5 optically reconfigurable nodes (20a-20f) optically connected along the first and the second optical carrier (2, 3) and adapted to communicate in pairs by means of respective links susceptible of failure, the ring network having a normal operative condition in which the nodes of each pair are optically configured so as to exchange optical signals on a respective working arc path at a respective first  
10 wavelength ( $\lambda_w$ ) on the first carrier (2) and at a respective second wavelength ( $\lambda_p$ ) different from said first wavelength ( $\lambda_w$ ) on the second carrier (3), said respective working path having a complementary arc path defining a respective protection arc path in which the first wavelength ( $\lambda_w$ ) on the first carrier (2) and the second wavelength ( $\lambda_p$ ) on the second carrier (3) can be used for further links and the  
15 first wavelength ( $\lambda_w$ ) on the second carrier (3) and the second wavelength ( $\lambda_p$ ) on the first carrier (2) are reserved for protection, characterized in that the ring network has a failure operative condition in which the nodes terminating a failed link are optically reconfigured so as to exchange optical signals on the respective protection arc path at the respective second wavelength ( $\lambda_p$ ) on the first carrier  
20 (2) and at the respective first wavelength ( $\lambda_w$ ) on the second carrier (3).
2. Ring network according to claim 1, wherein each of said plurality of reconfigurable nodes (20a-20f) is adapted to manage a predetermined subset of wavelengths within a set of transmission wavelengths ( $\lambda_1, \lambda_2, \dots, \lambda_N$ ) and includes  
25 a first and a second optical add/drop multiplexer (4, 5) serially connected to said first and, respectively, second carrier (2, 3) to feed/extract said subset of wavelengths to/from said first and, respectively, second carrier (2, 3), and to pass-through the remaining wavelengths of the set of transmission wavelengths ( $\lambda_1, \lambda_2, \dots, \lambda_N$ ).
3. Ring network according to claim 1, wherein each of said plurality of reconfigurable nodes (20a-20f) includes at least an optical transmitter (Tx<sub>i</sub>), at least an optical receiver (Rx<sub>i</sub>) and a reconfigurable optical switch unit (15; 15'; 15"; 115'; 115") selectively coupling said optical transmitter (Tx<sub>i</sub>) and said  
35 receiver (Rx<sub>i</sub>) to said first and second carriers (2, 3).

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4. Ring network according to claim 3, wherein each of said plurality of reconfigurable nodes (20a-20f) includes information insertion devices (TxTs) selectively optically connectable to said at least an optical transmitter (Tx<sub>i</sub>) and adapted to insert signalling information into the optical signals and information
- 5 extraction devices (RxTs) selectively optically connectable to said at least an optical receiver (Rx<sub>i</sub>) and adapted to extract signalling information from the optical signals.
- 10 5. Ring network according to claim 4, wherein said information insertion devices (TxTs) and said information extraction devices (RxTs) include optical transponders optically coupling said optical switch unit (15; 15'; 15"; 115'; 115") to said first and second carrier (2, 3) and adapted to change the signals wavelengths.
- 15 6. Method to autoprotect an optical ring network, said ring network including a first and a second optical carrier having opposite transmission directions and a plurality of nodes optically connected along the first and the second optical carrier and adapted to communicate in pairs in order to define bidirectional links, each pair including a first and a second link termination node adapted to mutually
- 20 communicate at respective first and second wavelengths, the method including:
- exchanging signals between the first and the second link termination node of each pair on a respective working arc path of said ring network by using the respective first wavelength on the first carrier and the respective second wavelength on the second carrier; said respective working path having a
  - 25 complementary arc path defining a respective protection arc path in which the first wavelength on the first carrier and the second wavelength on the second carrier can be used for further links and the first wavelength on the second carrier and the second wavelength on the first carrier are reserved for protection;
  - 30 - checking if a failure is present in the ring network producing at least a failed link; and
  - optically reconfiguring, in the presence of a failure, the link terminating nodes of said at least a failed link so that they exchange signals on the
  - 35 respective protection arc path by using the respective first wavelength on the second carrier and the respective first wavelength on the second carrier.

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7. Method according to claim 6, wherein each node of said plurality of nodes is adapted to manage a predetermined subset of wavelengths within a set of transmission wavelengths carried by the first and the second carrier, said step of exchanging including optically separating, at each node of said plurality of nodes,  
5 each wavelength of the respective subset of wavelengths from the set of transmission wavelengths.
8. Method according to claim 6, wherein the step of checking includes verifying, in each node of said plurality of nodes and for each wavelength of the respective  
10 set of wavelengths, if signals are received.
9. Method according to claim 6, wherein said step of checking includes verifying, in each node of said plurality of nodes and for each wavelength of the respective set of wavelengths, if signals are received degraded.  
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10. Method according to claim 6, wherein said step of checking includes verifying, in each node of said plurality of nodes and for each wavelength of the respective set of wavelengths, if signals include a failure message.
- 20 11. Method according to claim 6, further including transmitting a failure message from a first link termination node of a pair to a second link termination node of the same pair if a signal transmitted from the second link termination node to the first link termination node is not received, or is received degraded, by the first link termination node.
- 25 12. Method according to claim 6, wherein said step of reconfiguring includes switching optical connections which selectively couple at least an optical transmitter and an optical receiver to said first and second carrier.
- 30 13. Reconfigurable node for an autoprotected optical communication ring network, comprising a receiving/transmitting module (6) including:
- an optical transmitter (Tx<sub>1</sub>) to generate a signal including information to be transmitted in the network;
  - an optical receiver (Rx<sub>1</sub>) to receive a signal including information transmitted  
35 in the network;

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- a first transmitting transponder ( $TxT_1(\lambda_x)$ ) for optically coupling to a first carrier (2) of the network and adapted to modulate a signal at a first wavelength ( $\lambda_x$ );
- a second transmitting transponder ( $TxT_1(\lambda_y)$ ) for optically coupling to the first carrier (2) and adapted to modulate a signal at a second wavelength ( $\lambda_y$ );
- 5 - a third transmitting transponder ( $TxT_2(\lambda_x)$ ) for optically coupling to a second carrier (3) of the network and adapted to modulate a signal at the first wavelength ( $\lambda_x$ );
- a first receiving transponder ( $RxT_2(\lambda_x)$ ) for optically coupling to the first carrier (2) and adapted to demodulate a signal having the first wavelength ( $\lambda_x$ );
- 10 - a second receiving transponder ( $RxT_2(\lambda_y)$ ) for optically coupling to the first carrier (2) and adapted to demodulate a signal having the second wavelength ( $\lambda_y$ );
- a third receiving transponder ( $RxT_1(\lambda_y)$ ) for optically coupling to the second carrier (3) and adapted to demodulate a signal having the second wavelength ( $\lambda_y$ );
- 15 - reconfigurable optical connections (22-25; 31-38; 41-48; 131-136; 141-146) to selectively connect:
  - the optical transmitter ( $Tx_1$ ) either to the first transmitting transponder ( $TxT_1(\lambda_x)$ ) or to the third transmitting transponder ( $TxT_2(\lambda_x)$ );
  - 20 • the first receiving transponder ( $RxT_2(\lambda_x)$ ) to the third transmitting transponder ( $TxT_2(\lambda_x)$ );
  - the second receiving transponder ( $RxT_2(\lambda_y)$ ) to the optical receiver ( $Rx_1$ ); and
  - the third receiving transponder ( $RxT_1(\lambda_y)$ ) either to the optical receiver ( $Rx_1$ ) or to the second transmitting transponder ( $TxT_1(\lambda_y)$ ).
- 25

14. Reconfigurable node according to claim 13, wherein the receiving/transmitting module (6) further includes:

- a further optical transmitter ( $Tx_2$ ) to generate a signal including information to be transmitted in the network;
- 30 - a further optical receiver ( $Rx_2$ ) to receive a signal including information transmitted in the network;
- a fourth transmitting transponder ( $TxT_2(\lambda_y)$ ) optically coupled to the second carrier (3) and adapted to modulate a signal at the second wavelength ( $\lambda_y$ );
- 35 and

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- a fourth receiving transponder ( $RxT_1(\lambda_x)$ ) optically coupled to the first carrier (2) and adapted to demodulate a signal having the first wavelength ( $\lambda_x$ );  
said reconfigurable optical connections (22-25; 31-38; 41-48; 131-136; 141-146) selectively connecting:
- 5       • the first receiving transponder ( $RxT_2(\lambda_y)$ ) either to the third transmitting transponder ( $TxT_2(\lambda_y)$ ) or to the further receiver ( $Rx_2$ );
  - the fourth receiving transponder ( $RxT_1(\lambda_x)$ ) to the further receiver ( $Rx_2$ ); and
  - 10       • the further optical transmitter ( $Tx_2$ ) either to the second transmitting transponder ( $TxT_1(\lambda_y)$ ) or to the fourth transmitting transponder ( $TxT_2(\lambda_y)$ ).
15. Reconfigurable node according to claim 13 or 14, characterized in that it is adapted to manage a predetermined set of wavelengths within a set of  
15       transmission wavelengths ( $\lambda_1, \lambda_2, \dots, \lambda_N$ ) including a first and a second optical add/drop multiplexer (4, 5) optically coupling the receiving/transmitting module (6) to said first and, respectively, second carrier (2, 3) to feed/extract said subset of wavelengths to/from said first and, respectively, second carrier (2, 3), and to  
20       pass-through the remaining wavelengths of the set of transmission wavelengths ( $\lambda_1, \lambda_2, \dots, \lambda_N$ ).
16. Reconfigurable node according to claim 13 or 14, wherein the reconfigurable optical connections (22-25; 31-38; 41-48; 131-136; 141-146) include 2x2  
25       switches.
17. Reconfigurable node according to claim 13 or 14, wherein the reconfigurable optical connections (22-25; 31-38; 41-48; 131-136; 141-146) include 1x2 and 2x1  
30       switches.
18. Reconfigurable node according to claim 16 or 17, wherein the reconfigurable optical connections (22-25; 31-38; 41-48; 131-136; 141-146) include discrete  
35       switching components.
19. Reconfigurable node according to claim 16 or 17, wherein the reconfigurable optical connections (22-25; 31-38; 41-48; 131-136; 141-146) include an  
      integrated switching matrix.



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**ABSTRACT**

An autoprotected optical communication ring network includes a first and a second optical carrier (2, 3) having opposite transmission directions and a plurality of optically reconfigurable nodes (20a-20f) optically connected along the first and the second optical carrier (2, 3) and adapted to communicate in pairs by means of respective links susceptible of failure, the ring network having a normal operative condition in which the nodes of each pair are optically configured so as to exchange optical signals on a respective working arc path at a respective first wavelength ( $\lambda_x$ ) on the first carrier (2) and at a respective second wavelength ( $\lambda_y$ ) different from the first wavelength ( $\lambda_x$ ) on the second carrier (3), the respective working path having a complementary arc path defining a respective protection arc path in which the first wavelength ( $\lambda_x$ ) on the first carrier (2) and the second wavelength ( $\lambda_y$ ) on the second carrier (3) can be used for further links and the first wavelength ( $\lambda_x$ ) on the second carrier (2) and the second wavelength ( $\lambda_y$ ) on the first carrier (3) are reserved for protection, the ring network having also a failure operative condition in which the nodes terminating a failed link are optically reconfigured so as to exchange optical signals on the respective protection arc path at the respective second wavelength ( $\lambda_y$ ) on the first carrier (2) and at the respective first wavelength ( $\lambda_x$ ) on the second carrier (3).



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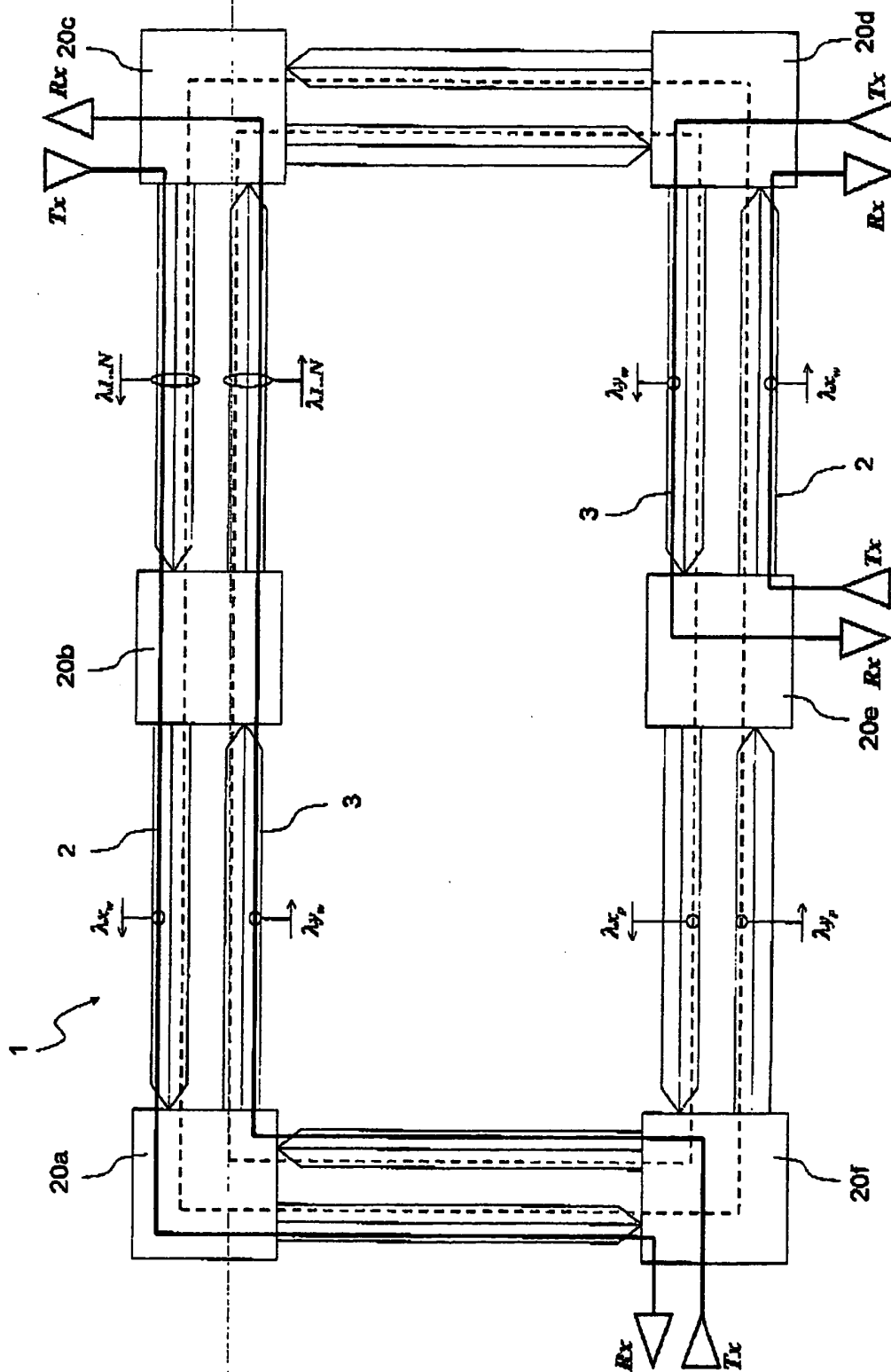


Fig. 2

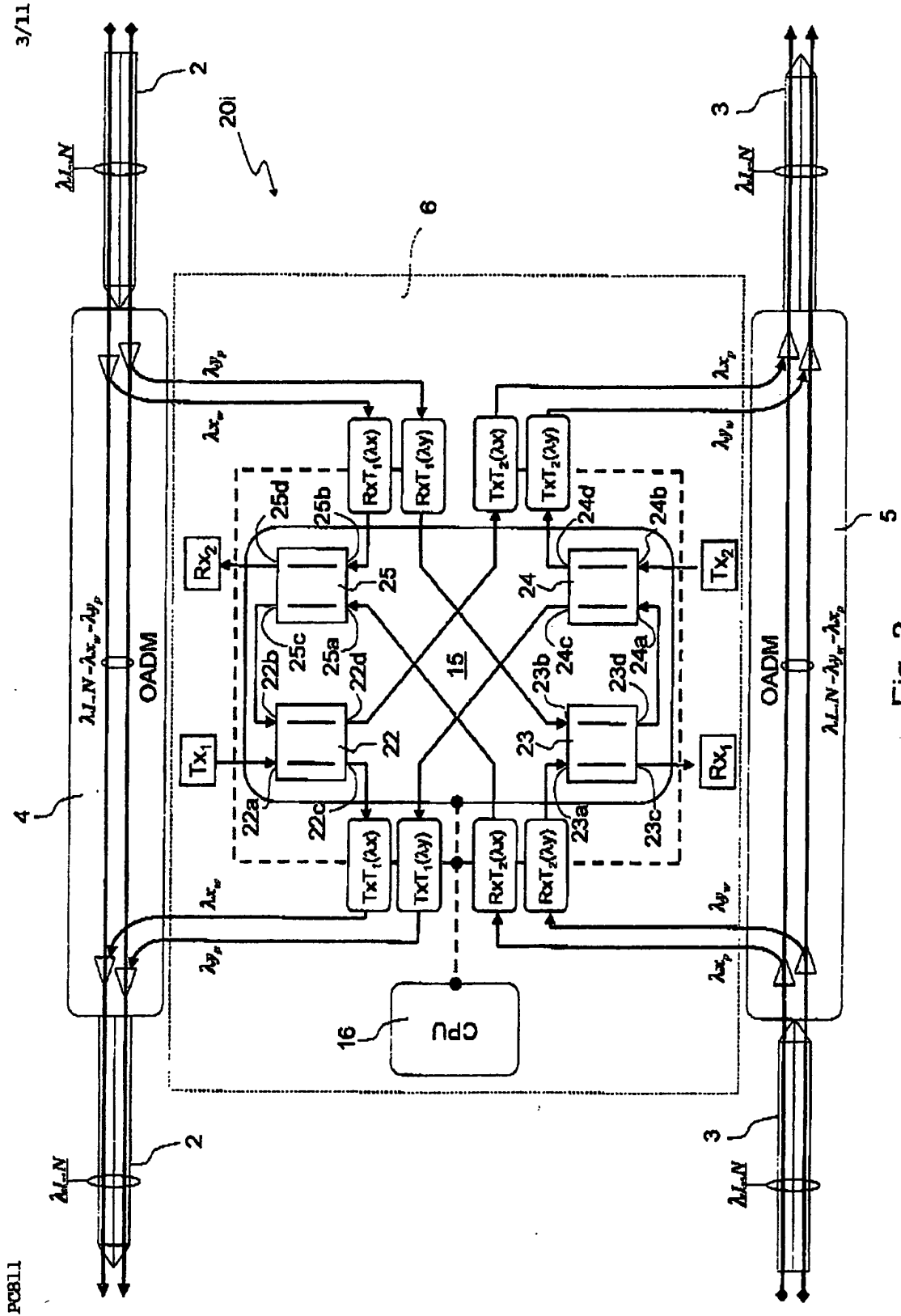


Fig. 3

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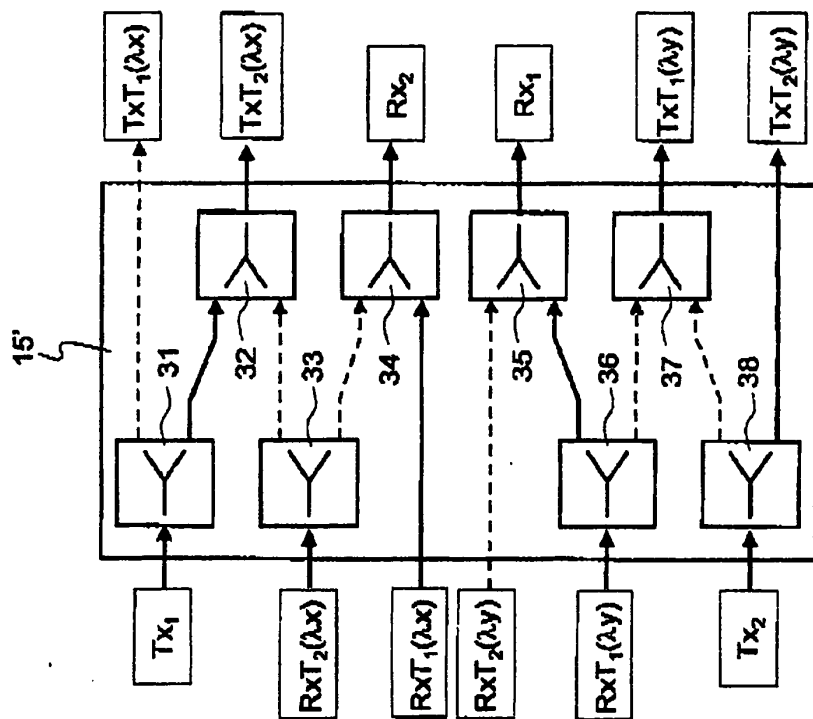


Fig. 11

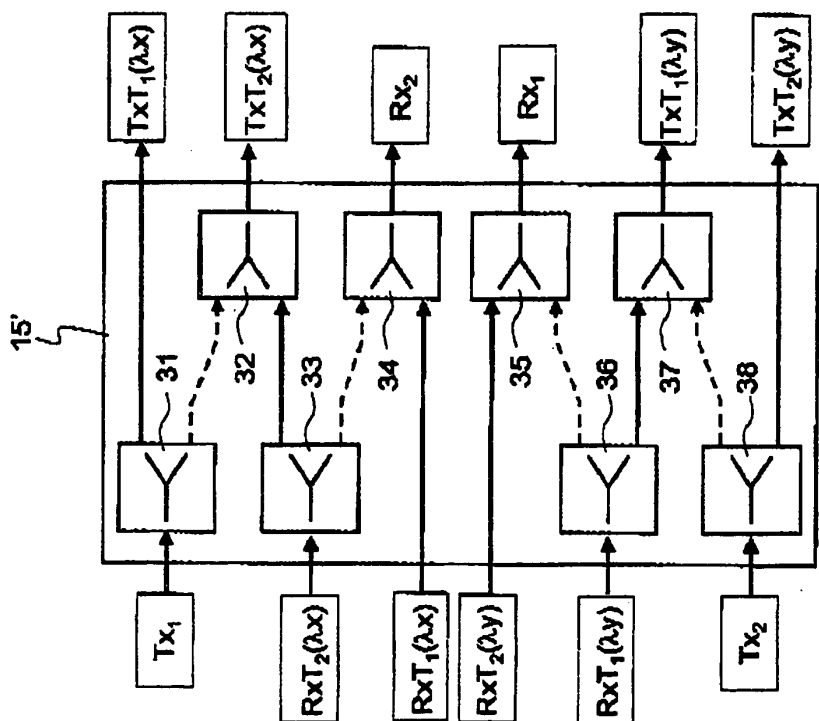


Fig. 4

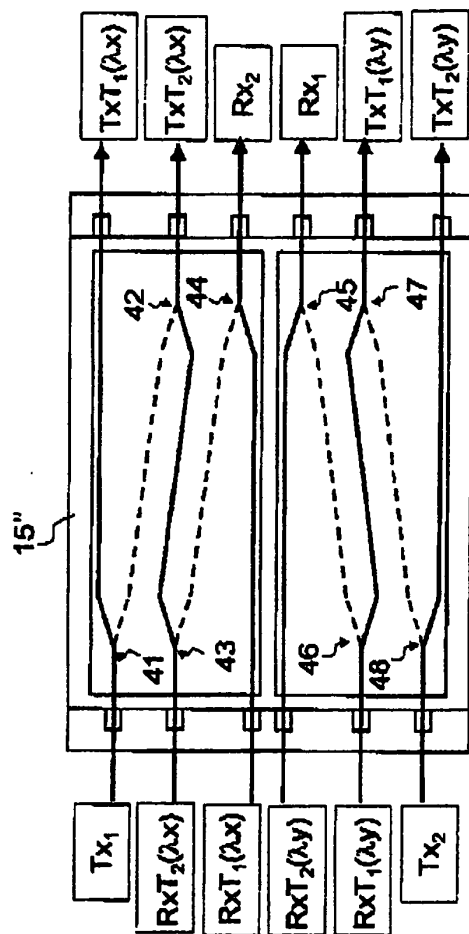


Fig. 5

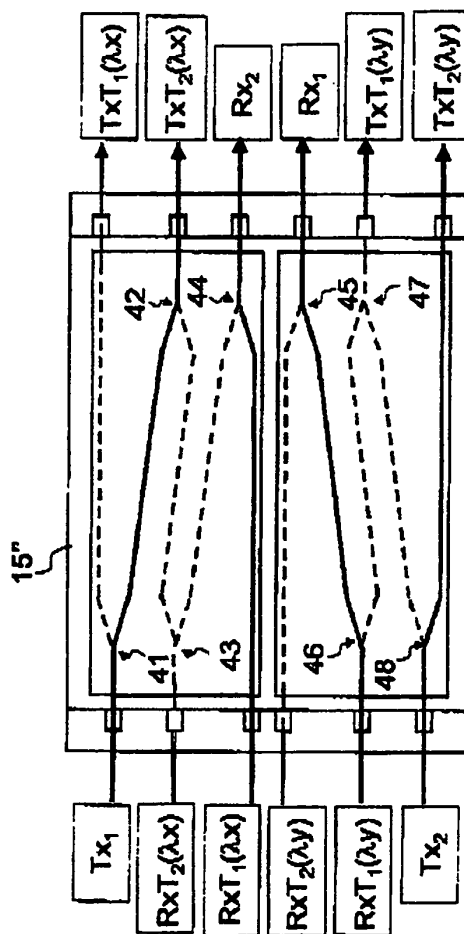


Fig. 12

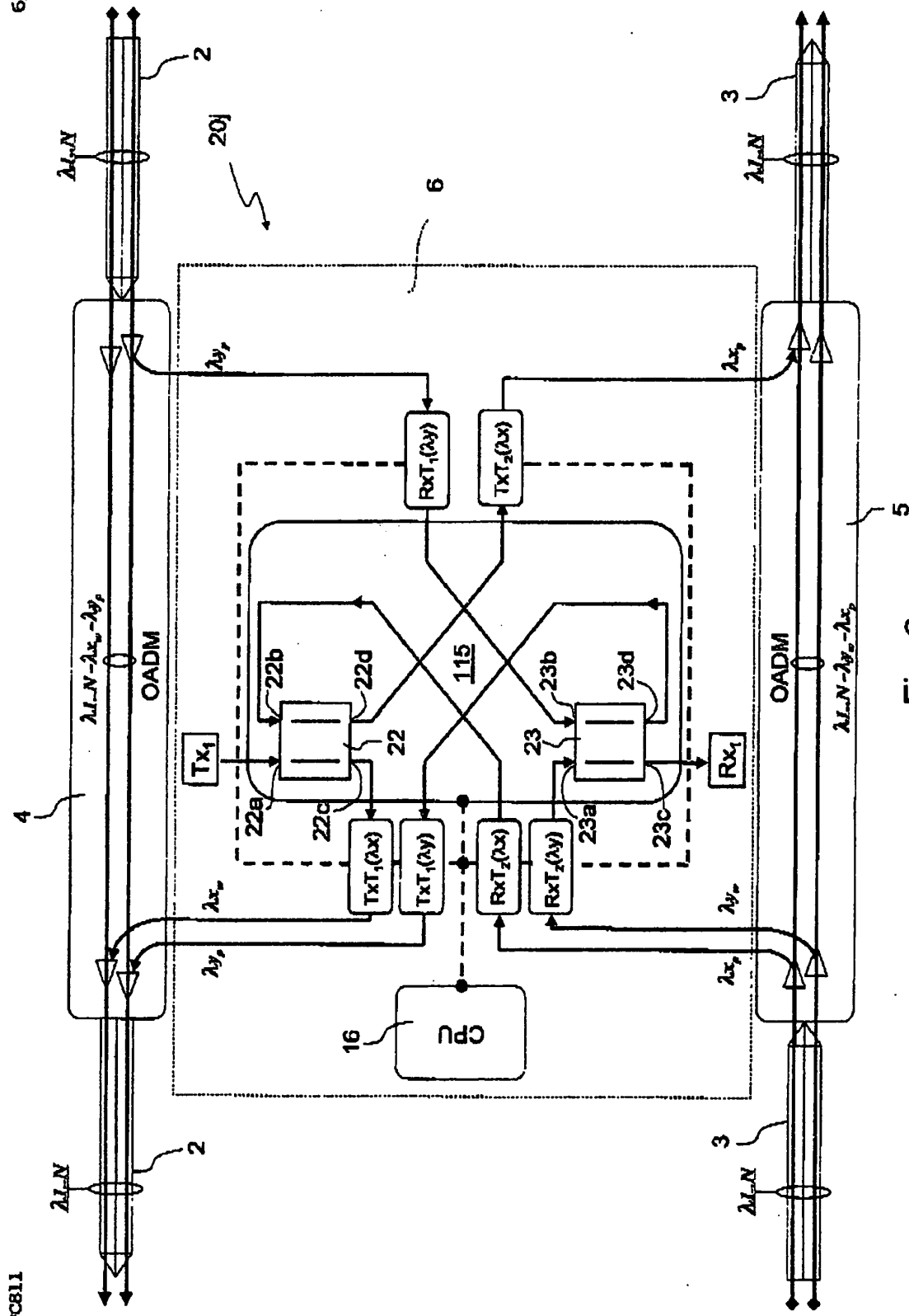


Fig. 6

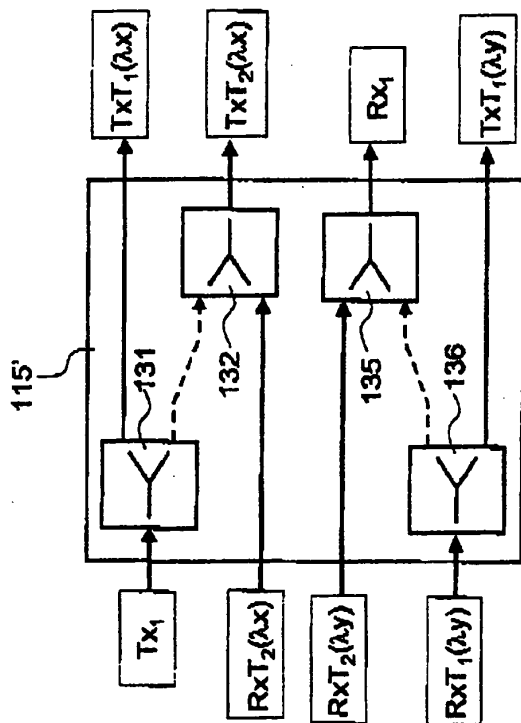


Fig. 7

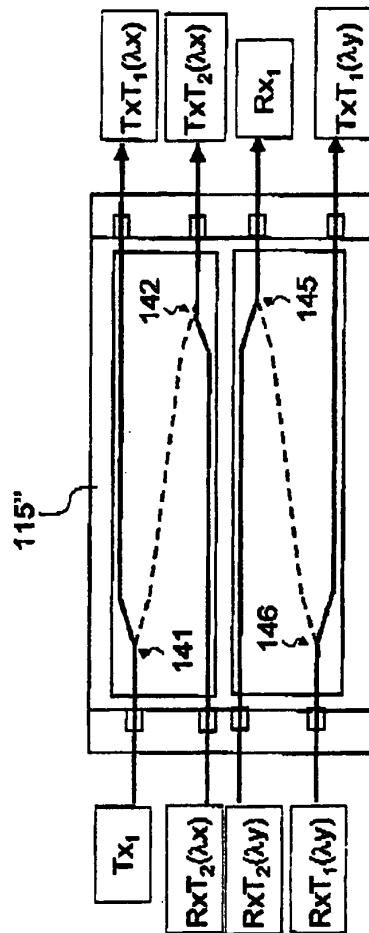
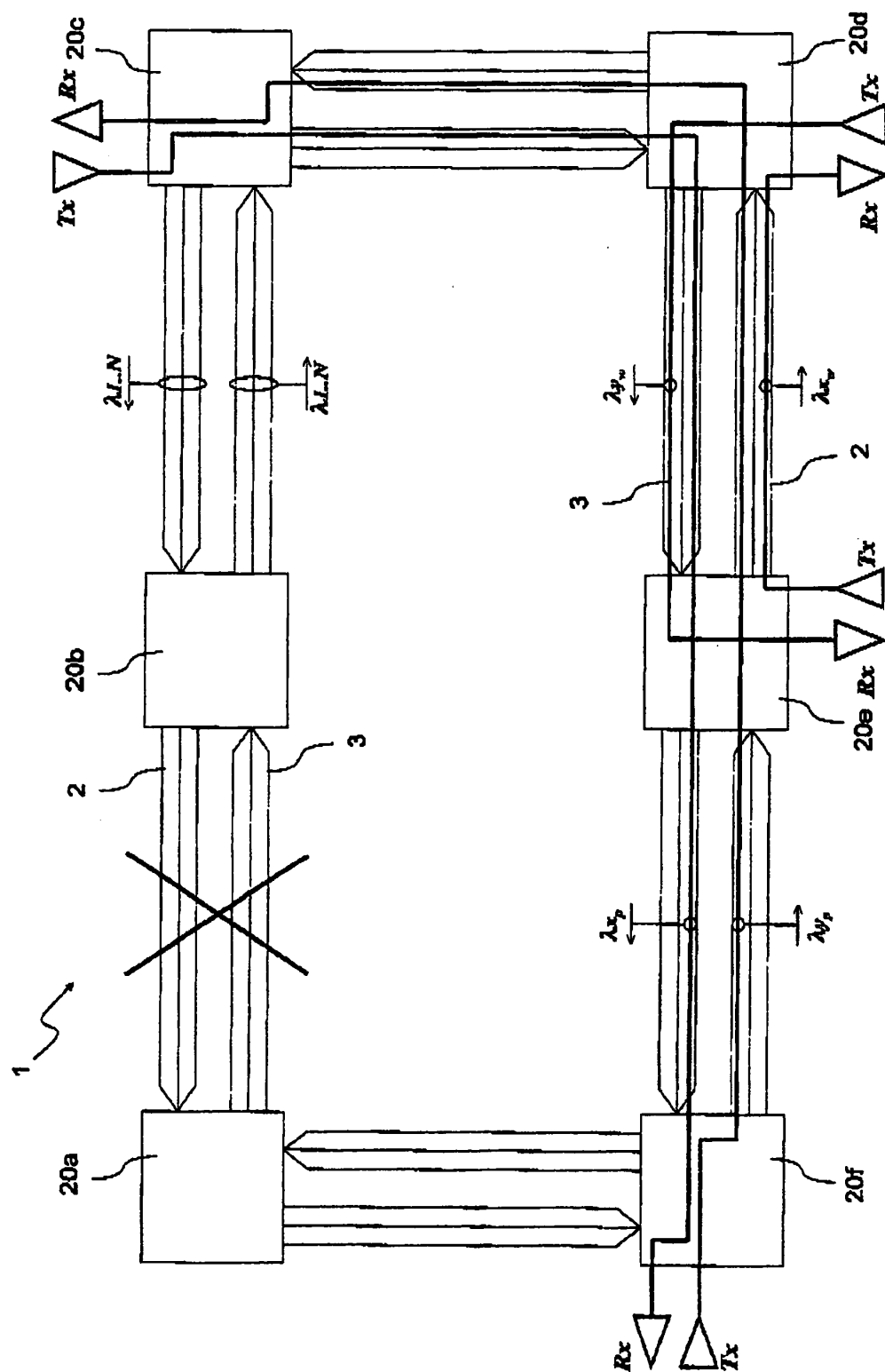


Fig. 8



**Fig. 6**

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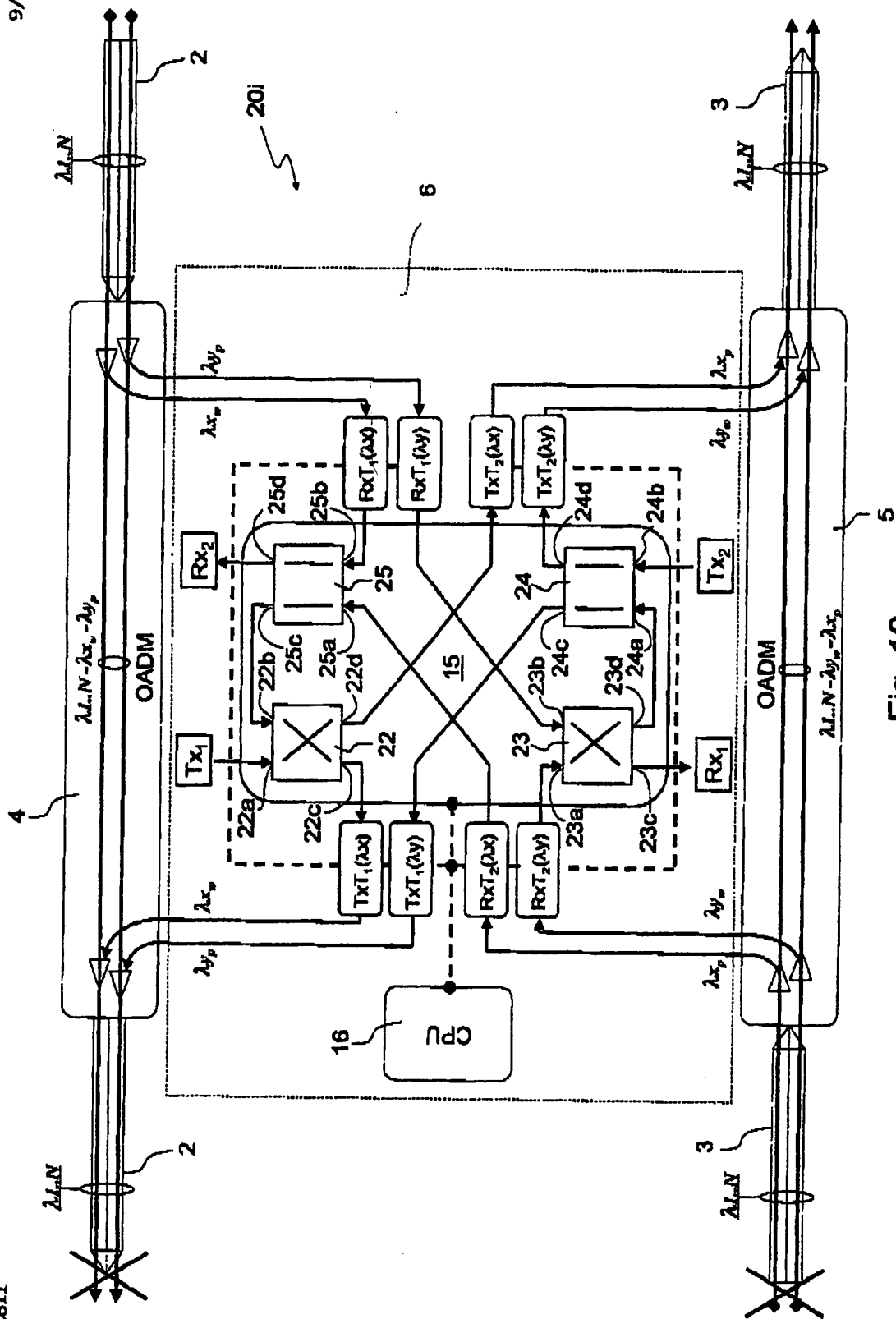


Fig. 10

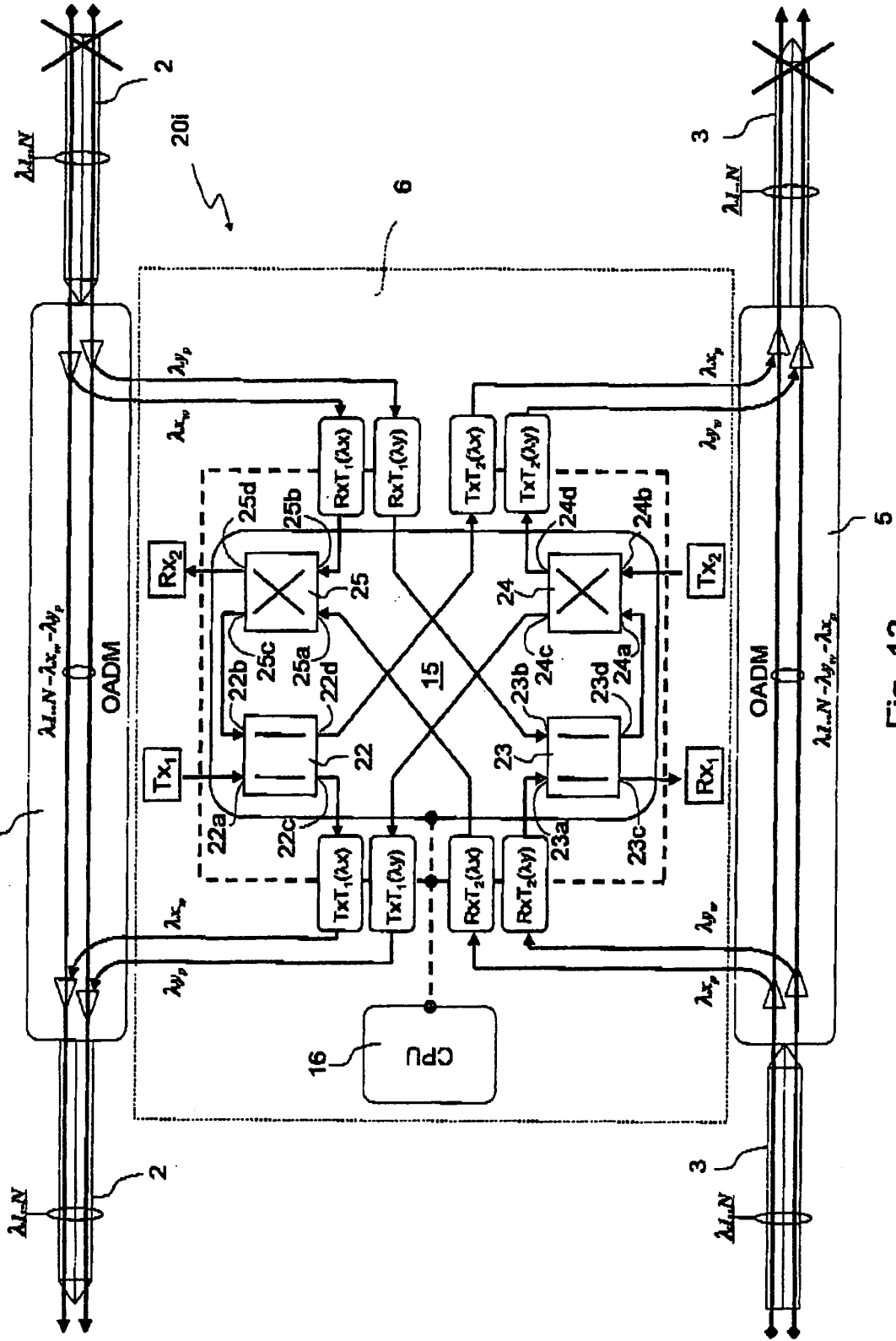


Fig. 13

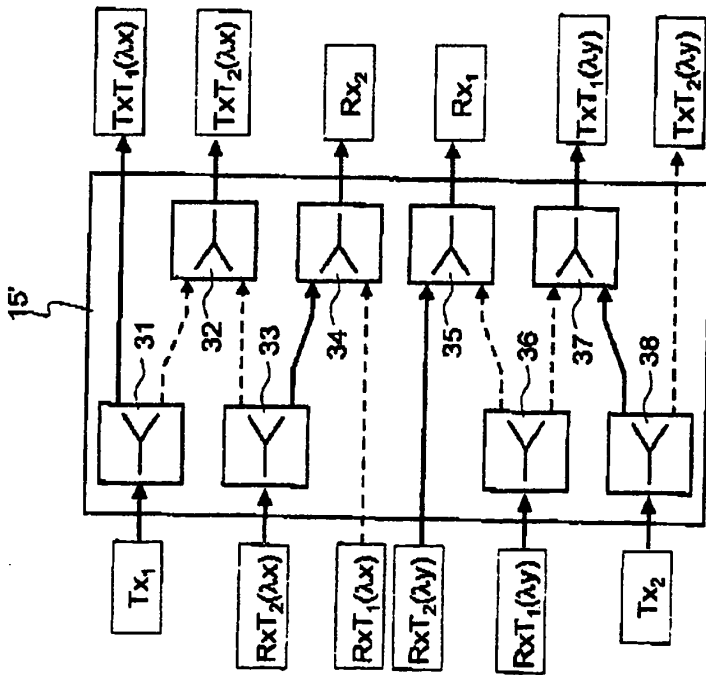


Fig. 14

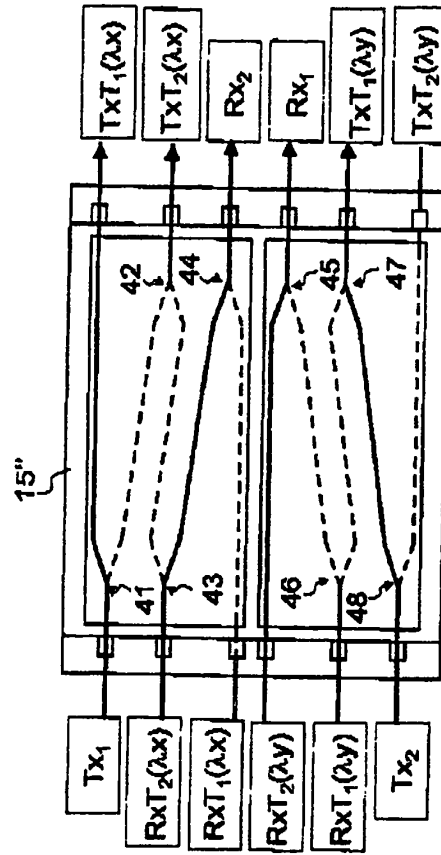


Fig. 15